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# THE SHIPBUILDING TECHNOLOGY TRANSFER PROGRAM

## PROGRAM SUMMARY REPORT

U.S. DEPARTMENT OF COMMERCE
MARITIME ADMINISTRATION
IN COOPERATION WITH
LEVINGSTON SHIPBUILDING COMPANY
AND
ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES

# Report Documentation Page

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TECHNOLOGY TRANSFER PROGRAM (TTP)

# PROGRAM SUMMARY REPORT

Prepared by:

August 31,1981

Levingston Shipbuilding Company
in conjunction with:
IHI Marine Technology Inc.

70427

# PREFACE

This report provides a summary of the reports emanating from the Shipbuilding Technology Transfer Program performed by Levingston Shipbuilding under a cost sharing contract with the U.S. Maritime Administration.

The material contained herein was developed from the study of the Engineering and Design programs and systems presently in operation in the shipyards of Ishikawajima-Harima Heavy Industries (IHI) of.Japan. Information for this study was derived from source documentation supplied by IHI, information obtained directly from IHI consulting personnel assigned on-site at Levingston, and from personal observations by two teams of Levingston personnel of actual operations at various IHI shipyards in Japan.

In order to place this study in context within the overall Technology Transfer Program, a brief overview of the program and its organization is provided in the following paragraphs:

## THE TECHNOLOGY TRANSFER PROGRAM (TTP)

The U.S. shipbuilding industry is well aware of the significant shipbuilding cost differences between the Japanese and ourselves. Many reasons have been offered to explain this differential and whether the reasons are valid or not, the fact remains that Japanese yards are consistently able to offer ships at a price of one-half to two-thirds below U.S. prices.

Seeing this tremendous difference first hand in their own estimate of a bulk carrier slightly modified from the IHI Future 32 class design, Levingston management determined to not only find out why this was true but to also attempt to determine precise differences between IHI and Levingston engineering and design practices; production planning and control methods; facilities, production processes, methods and techniques; quality assurance methods; and personnel organization, operations and training. The obvious objective of such studies was to identify, examine and implement the Japanese systems, methods and processes which promised a significant improvement in the Levingston design/production process.

With this objective in mind, and recognizing the potential application of the TTP results to the American shipbuilding industry, Levingston initiated a cost-sharing contract with MarAd to provide documentation and industry seminars to reveal program findings and production improvement results measured during production of the bulkers. Subsequently, Levingston subcontracted with IHI Marine Technology Inc. (an American corporation and a subsidiary of IHI, Japan) specifying the areas to be explored and the number and type of IHI consulting personnel required during the period of re-design and initial construction of the first bulker.

Basically, the program was organized into six major tasks:

1 - Cost Accounting

2 - Engineering and Design

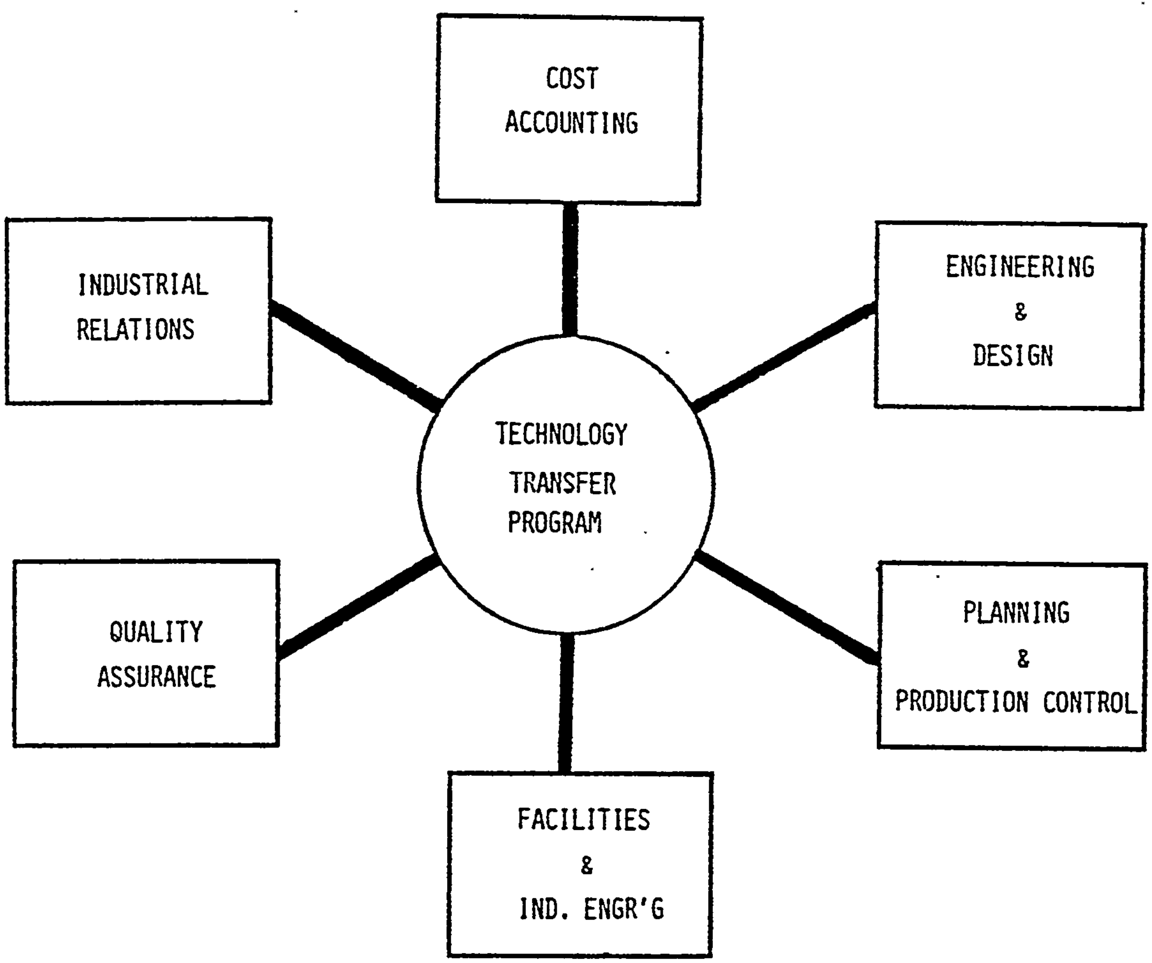
3 - Planning and Production Control

4 - Facilities and Industrial Engineering

5 - Quality Assurance

6 - Industrial Relations

Beneath each of these major tasks is a series of sub-tasks which further delineated discrete areas of investigation and study. Each sub-task was planned and scheduled to: 1) study IHI systems, methods and techniques; 2) compare the Levingston and IHI practices; 3) identify improvements to the Levingston systems; 4) implement approved changes; 5) document program findings, changes to the Levingston systems, and the results of those changes; and 6) disseminate program findings and results to industry via MarAd.



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# INTRODUCTION

## PROGRAM HISTORY

The Shipbuilding Technology Transfer Program was initiated in October, 1978, in conjunction with Levingston's signing of a five ship bulker program, each of which were to be built to a modified design of the Ishikawajima-Harima Heavy Industries (or IHI) Future 32 class bulk carrier. Levingston engaged IHI to assist in the redesign of the IHI ship and to provide assistance in the study and refinement of Levingston's production system.

The Technology Transfer Program was established having three objectives: to study the Japanese technology applied at their shipyards; to apply the Japanese technology that appeared to be of benefit to Levingston; and as part of the contract with the Maritime Administration to share its findings, conclusions and results with the U.S. shipbuilding industry. The program was structured over a period of thirty months beginning in October, 1978, and ending in March of 1981.

As mentioned in the Preface the program was broken down into six discrete areas. The first area, that of cost evaluation, was initiated soon after contract signing to provide a basis for the investigations to be initiated in the other task areas. The objective behind this cost evaluation was to determine those areas where the greatest differences of cost occurred between Levingston and IHI and using this indicator proceed to examine the reasons for these differences. As it turned out, most of the areas indicated significant differences and it was determined at that time that a study of the entire IHI system and the corresponding Levingston system would have to be undertaken.

Program activities were designed to have Levingston and IHI consulting personnel work side by side in the study of the IHI system/processes and methods while other Levingston personnel documented the existing Levingston system. After the initial study of the IHI system and the documentation of the Levingston system, both would be compared and the significant differences noted for further study. Out of this study effort any apparent changes that were recognized and that would obviously be beneficial to the Levingston system were recommended and if approved were implemented. The final stages of the program were to be concerned with the documentation of the findings and conclusions from the study and the results from any of the aspects of the IHI system that had been adopted. The dissemination of this data to industry was to be effected through MarAd.

This dissemination was to occur in two ways: through the issuance of final reports in each of the task areas and through seminars to be prepared and conducted by Levingston personnel.

The issuance of this Program Summary Report concludes the program. Reports distributed to industry as a consequence of the program are as follows:

| Report No. | Title | Issue Date |
|---|---|---|
| 2123-1.0-4-1 | Cost Accounting | March, 1981 |
| 2123-2.0-4-1 | Engineering & Design | December, 1980 |
| 2123-3.0-4-1 | Planning & Production Control | November, 1980 |
| 2123-4.0-4-1 | Facilities & Industrial Engineering | June, 1981 |
| 2123-4.1-4-1 | Standards | June, 1981 |
| 2123-5.1-4-1 | Quality Assurance | March, 1980 |
| 2123-5.1-4-2 | Accuracy Control Planning | March, 1980 |
| 2123-6.1-4-1 | Industrial Relations | March, 1980 |
| 2123-0.0-4-1 | Program Summary | June, 1981 |

Additionally, bound copies of the slides presented at the two seminars - (1) The Concept and Application of Accuracy Control and (2) Organization for Production and the Personnel System were distributed to Seminar attendees.

Two 20-minute narrated slide presentations entitled "The IHI Aioi Shipyard" and "Aspects of the Personnel System" were submitted to MarAd.

All of the above documentation together with all source data were organized into a program Data Bank and submitted to MarAd in micro-fiche form (5 copies).

## REPORT ORGANIZATION

This summary report is organized into six sections paralleling the organization of program task elements and the final reports. These sections are:

| SECTION | SUBJECT |
|---|---|
| 1 | Engineering & Design |
| 2 | Planning & Production Control |
| 3 | Facilities & Industrial Engineering |
| 4 | Standards |
| 5 | Quality Assurance |
| 6 | Industrial Relations |

# SECTION 1

# ENGINEERING & DESIGN

## SECTION 1

## ENGINEERING & DESIGN

### DESIGN INITIATION

The design and engineering function at IHI is responsible for ship design and the dissemination of design and construction information to Production. This design and engineering activity is accomplished by a "top-down" refinement procedure which begins with a conceptual ship design determined through research and design teams at the IHI Head Office. This conceptual design is refined to become the basic design. Figure 1-1 describes the flow as the conceptual design is transformed from concept to basic guidelines, to functional diagrammatic design and finally to detail design.

### BASIC DESIGN AT THE IHI TOKYO HEAD OFFICE

The basic design group of the IHI Head Office (Tokyo) is composed of approximately 100 persons primarily involved in creating the design of new vessels to be built at one of the IHI shipyards. Working in conjunction with the Marketing Survey Group, the Initial Development Group, and the Sales and Estimation groups, the Basic Design Group develops a conceptual ship design into a basic design package which consists of specifications, ships lines, general arrangement drawings, midship section drawings and naval architectural data and calculations.

The basic design office is organized into three groups according to vessel size and functional responsibilities as illustrated in Figure 1-2. The No. 1 Basic Design Group for small and medium size vessels and the No. 2 Basic Design Group for large vessels (super tankers) are referred to as "think tanks". The educational level of these groups is high with 85% holding college or university engineering degrees.

In support of these two groups is the No. 3 Basic Design Group which is further broken down into four groups: 1) the Administration

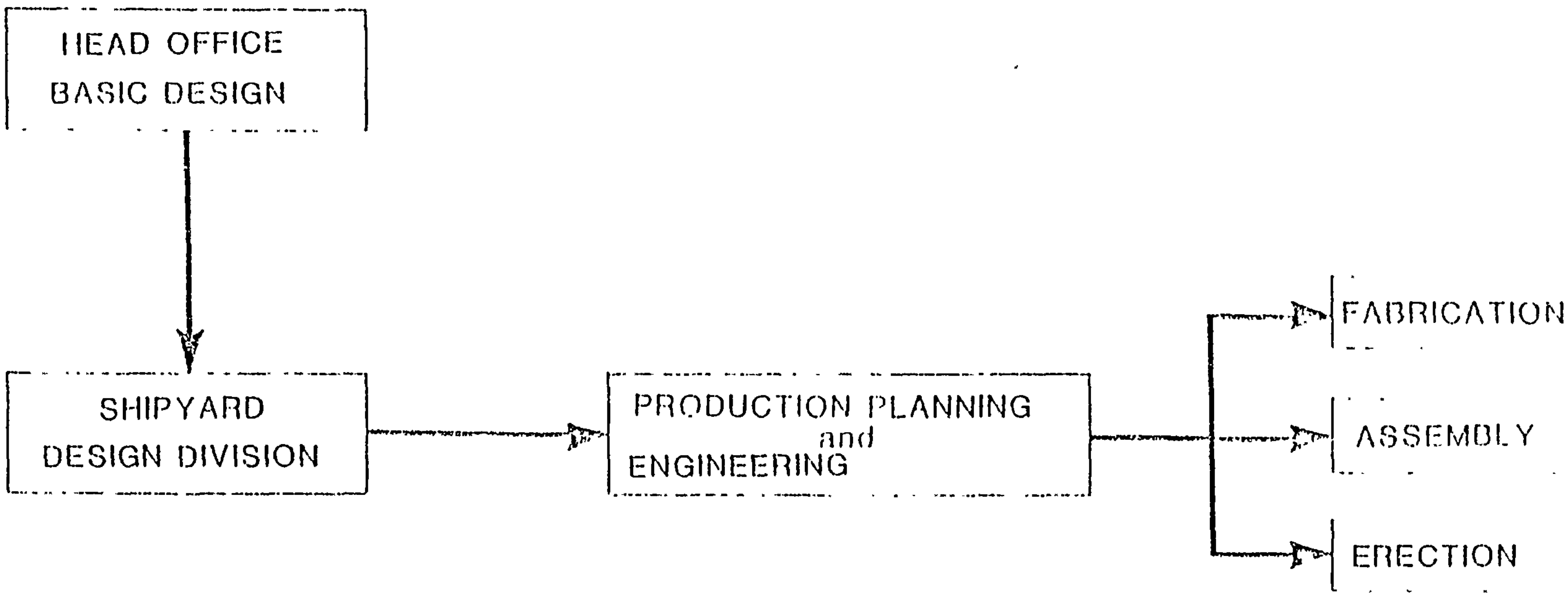



FIGURE 1-1

BASIC FLOW OF DESIGN FOR PRODUCTION

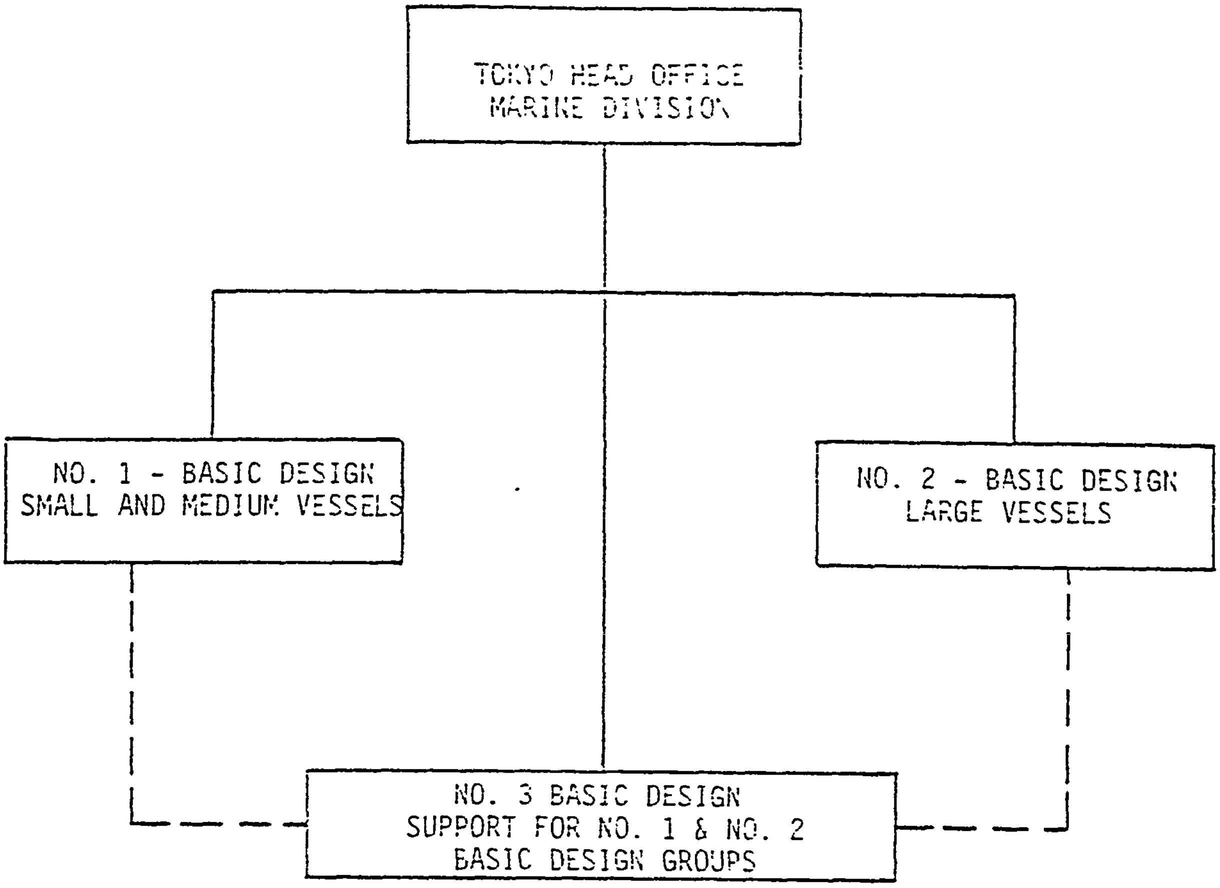



**FIGURE 1-2**

**BASIC DESIGN OFFICE**

Group which performs the clerical functions of the department; 2) the Ship's Form Group; 3) the Hull Structure Group both of which are composed of naval architects; and 4) an Electric Group composed of electrical engineers.

The Basic Design package is the basis for the development of the Key Plans for the ship being designed. Computer output is utilized in preparation of the key plans as the drawings are rapidly produced at 1/100th scale. These drawings are not finished at the head office but are transferred to a shipyard to be completed.

A preliminary blocking plan, or unit breakdown, is also prepared at the head office to be finalized at the shipyard selected to build the vessel.

SHIPYARD DESIGN & ENGINEERING ORGANIZATION

The Shipyard Design Group is directly responsible to the Shipyard General Superintendent and is divided according to the following major functions: basic design, key plan, yard plan, and computerization. The functions of these groups begin upon receipt of basic design data from the-head office design division.

The shipyard's basic design group is responsible for maintaining specifications , customer requirements, and general arrangement drawings. This group also provides detail naval architectural data.

The key plan group prepares detail scantling data, schematic diagrams and functional plans, purchase order specifications, lists of materials for procurement, outfitting materials fabrication drawings, and material lists for fabrication drawings.

The yard plan group, or working drawing group, prepares detail fabrication drawings, detail outfitting drawings, material lists for outfitting, pipe piece manufacturing drawings, and material lists for pipe piece manufacturing drawings. Figure 1-3 illustrates the organization of the shipyard design department and Table T1-1 lists the specific functions of each group.

## TYPICAL DESIGN SYSTEM AND FLOW

Through cooperation of all sections of the Shipyard Design Department, the basic drawings are finalized and submitted to the ship owner for approval. The drawings are then distributed to the various sections of the yard's design department to become Key Plans and eventually Yard Plans.

The basic design drawings consist of general arrangement, ship's lines, preliminary machinery arrangement, miship section, specifications, and calculations. These data are expanded to make up the Key Plans. The Key Plans describe the vessel in further detail in areas such as the fore body and after body. These drawings will then become the basis for the working drawings or Yard Plans.

The basic flow of drawings is illustrated in Figure l-4. Table T1-2 shows the major items produced by the shipyard design organization.

### Development of Key Plans

The key plans and hull calculations are prepared by the key plan teams of the Hull Structural Design Group, the Hull Fitting Design Group and the Accommodation Design Group. The structural design is analyzed using IHI computer programs "Z Plate" and Z Vibra" (see Appendices). The outputs from these programs are both printed and plotter-drawn.

Standardization and computerization significantly enhance the productivity of the design function. Many drawings are rapidly produced on a drum plotter, thus utilizing the computer data bank of ship's information. The Hull Structure Group prepares the loading information

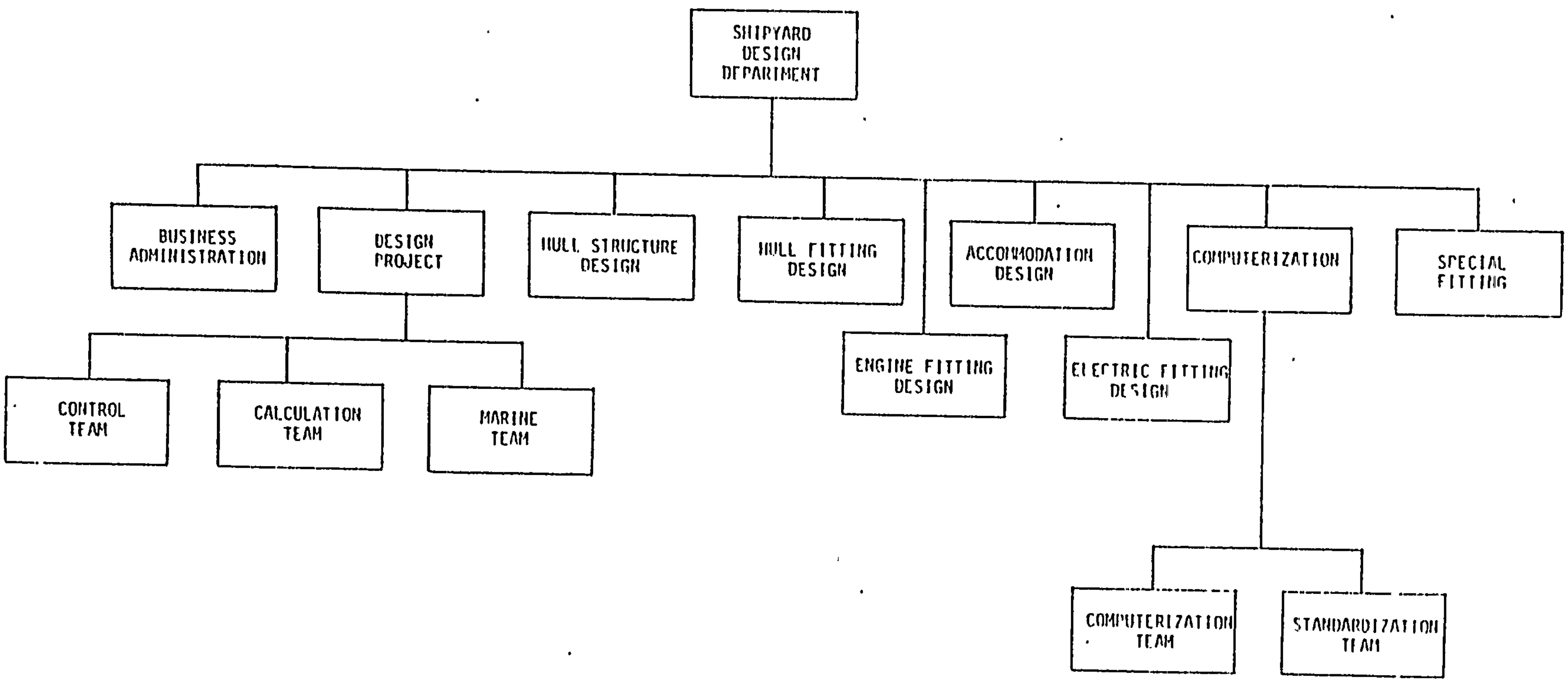



FIGURE 1-3

DESIGN DEPARTMENT ORGANIZATION

TABLE T1-1

MAJOR FUNCTIONS OF SHIPYARD DESIGN DEPARTMENT GROUPS

1. Business Administration Group

* General service for each design section
* Drawing schedule
* Working schedule
l Estimations

2. Project Design Group

a. Control Team l Administration of each design group
b. Calculation Team * calculation of ship's properties
 * Tonnage measurecent
c. Marine Team * Consultant dark and drawing supply for overseas shipyards

3. Hull Structure Design Group

* Key plans of hull structure
l Yard plans of hull structure
* Block (unit) arrangement
* List of hull structural members including height and fillet weld length

4. Hull fitting Design Group

l Key plans of hull fittings and piping
* Purchase order specifications for fittings
* fitting arrangement plans
* production drawings of hull piping and outfitting
* MLF , MLS

5. Accommodation Design Group

* Key plans of accommodations quarters
* Coiner arrangement
* List of upholsteries and fittings
* Purchase order specifications
* Production drawings of accommodations quarters
* Key plans and yard plans of superstructure

0. Engine Fitting Group

* Machinery arrangement
* Piping diagram of engine room
* Purchase order specification
* sea trials plans
* Production drawings of engine room
* Funnel fittings
l Tanks and auxiliary foundations

7. Electric Fitting Design Group

* Wiring diagram
* Purchase order specifications
* Electric fitting arrangement
* Equipment for lighting and cable installation

8. Computerization Group

* Systems and programs development
* Maintenance of programs and manuals
* Standardization of fittings

9. Special Fitting Design Group

* Design of cargo gears and hatch Covers
Design of rampways, stern and bow doors, special racks and carriers, etc.
* Purchase order specifications
* Heavy lifts, dredging, etc.

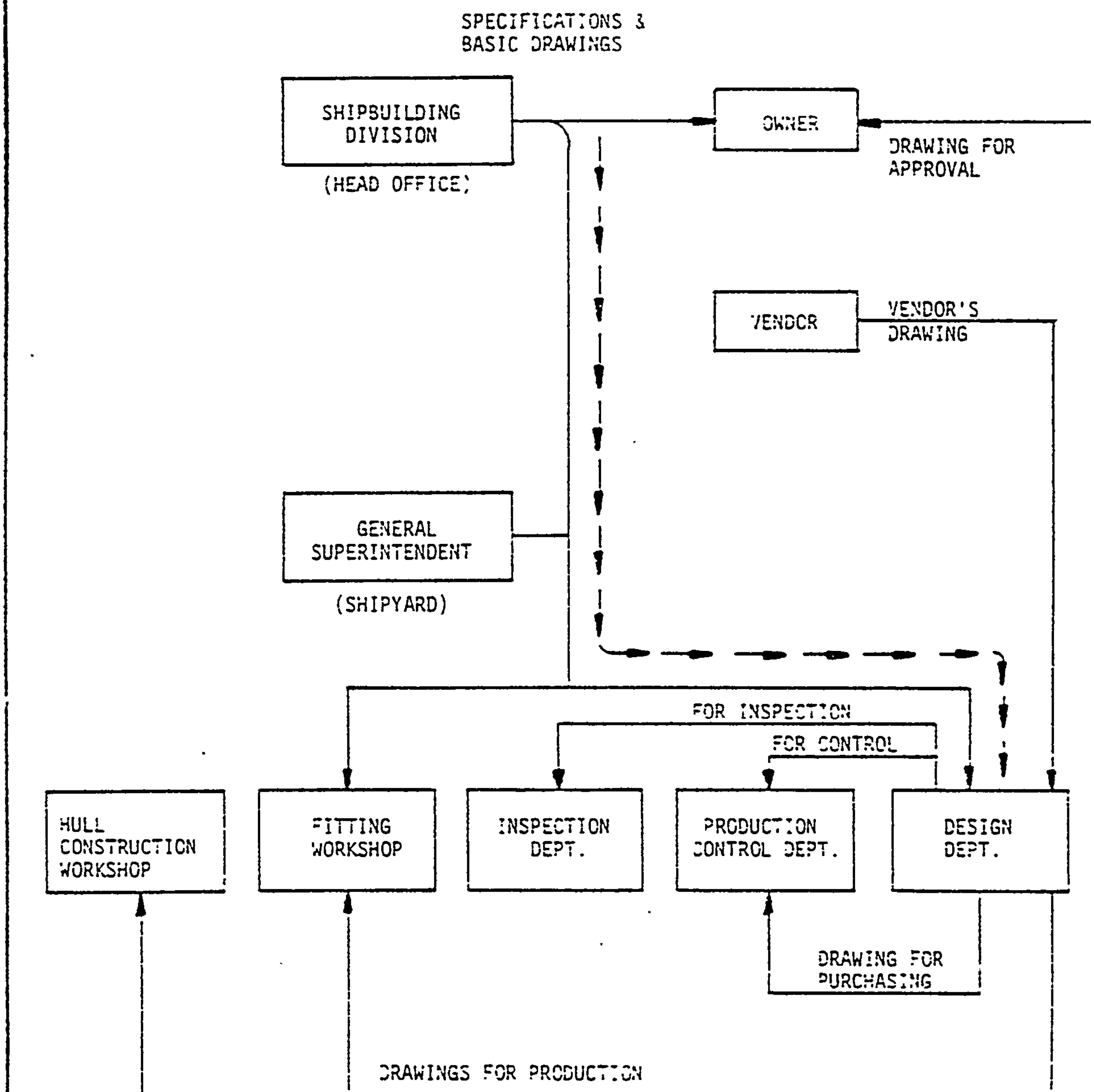



FIGURE 1-4

BASIC FLOW OF DRAWINGS

## MAJOR ITEMS PRODUCED BY SHIPYARD DESIGN ORGANIZATION

### *OUTFITTING KEY PLANS

- Machinery Arrangement
- Joiner Arrangement
- Piping Diagram
- Purchase Order Specifications (Main Machinery)
- MLS (Long Term Delivery Items)
- MLS (Material List by Systems)

### HULL KEY PLANS

- Hull Scantling
- Unit Weight (Approx.) Preliminary Unit Arrangement
- Midship Section & Typical Transverse Bulkhead
- Stern & Rudder
- Main Eng. & Equip. Foundations
- Plan of Welding
- Stress & Vibration Research

### *OUTFITTING YARD PLANS

- Compartment Arrangement
- Pallet List
- Composite Drawings
- Manufacturing Drawings (MLP, MLC) Manufacture of Pipe and other Components
- Module Assembly Drawing
- On-Unit Fitting Drawing
- MLF
- Purchase Order Specs (Short Term Delivery Items)
- On-Board Fitting Drawings

### HULL YARD PLANS

- Unit Arrangement
- Unit Weights - Exact
- Unit Center of Gravity
- Welding Length
- Working Drawings & Structural Details
- Piece List
- Auxiliary Equipment Foundation Drawings

*Outfitting Design is divided into deck, accommodations, machinery and electric groups.

TABLE T1-2

for the data base which in turn produces the shell landing data. This input is normally entered via CRT but may be prepared manually and checked on a graphic display. The plotter is suitable for lines and shell expansion drawings and is also utilized for structural analysis by producing drawings which show structural diagrams and plotted stress locations.

The data are also used by the mold loft which is equipped with remote stations composed of a CRT and three large, automatic flat-bed drafting tables. Through these machines, design information reaches Production in the form of 1/10 scale, highly accurate, shape templates used in the fabrication of hull parts.'

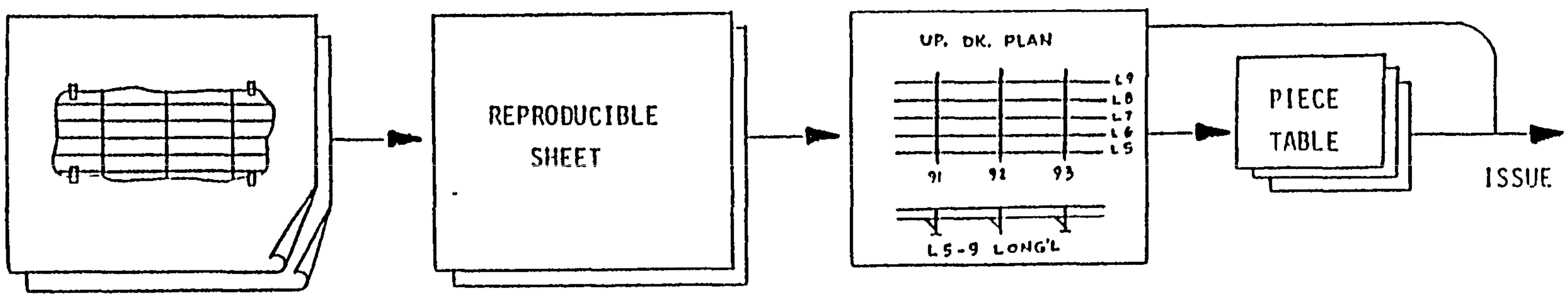
Development of Yard Plans

The next step in the shipyard's engineering process is the preparation of Yard Plans or working drawings. All hull structural detail information, block (or unit) arrangement, unit weights, weld lengths, center of gravity of units, piece lists and auxiliary foundation drawings are developed at this time.

The IHI drawing system is structured in such a way that a minimum of re-drawing is necessary. The drawings and material lists are prepared by various sophisticated photographic methods as well as computerized and manual drawing techniques.

The yard plan drawings are made according to the unit arrangement and consist of a title sheet and several sheets comprising the structure and details of an individual unit. Figure 1-5 depicts the process flow for preparation of the Yard Plans.

The issuance of the Yard Plans usually begins at K-3-1/2 (keel lay minus three and one-half months). Table Tl-3 describes the




Parts of Key Plans are cut out, arranged and pasted up for reproduction. Key Plans are 1/100 scale.

Reproducible sheet is photographically enlarged to 1/50 scale.

Details, sections and other descriptions are added manually.

Piece tables are made for each unit including piece descriptions, piece weights and unit weight.

FIGURE 1-5

PROCESS FLOW OF YARD PLAN PREPARATION

## TABLE T1-3

## CONTENTS OF YARD PLANS

1. Principal Material List - the basic list of all materials to be used. By studying this list, the volume of fabrication work can be estimated.

2. Drawinq List (MLA) - the kinds of drawings to be prepared by the yard's design department and the dates of completion.

3. Arrangement Drawings - indicate the arrangement of the ship as a whole, as well as the arrangement of the main equipment. These drawings describe the types of fabrication work to be done and serve as the basis for the fitting drawings. The block (or unit) arrangement shows all blocks of the vessel and provides the frame of reference for design and production of each vessel.

4. Body Plan (Hull Construction) - provides details of the hull structure and serves as a basis for the fitting drawings.

5. Diagrams - Indicate the functional systems of all outfitting equipment and serve as a basis for fitting drawings. Some diagrams are used directly in outfitting work as well as for systems performance checking.

6. Practices - contain the items of agreement or rules for actually carrying out the design work as well as fabrication work. They contain detailed instructions not found in the specifications.

7. Manufacturer's Drawings - are drawings of the auxiliary machinery to be fitted on the ship. The drawings are used by sub-contractors in the manufacture of items not made in the yard. They are used as reference material for the installation and operation of equipment.

8. Fitting Drawings - indicate the mounting positions of outfitting equipment and are the main drawings used by the Outfitting Department. Virtually all actual fitting work is done on the basis of these drawings. They are prepared by work stage and work zones.

9. Materials List (MLF) - contains all outfitting materials necessary for advancing the work based on the fitting drawings.

10. Piece Tables - are used when manufacturing pipes and are the basic drawings used at the pipe shop. The pipes in the fitting drawings are picked up one by one and a drawing is prepared for each. These drawings are grouped by MLF units.

actual contents of the numerous and varied drawings and the list of yard plans that are actually distributed to the worksites.

HULL CONSTRUCTION ENGINEERING

Shipyard design activities typically accomplish a great deal of the production planning associated with the development of the detailed working drawings. However, the principal activities of the design division of the yard are to identify and define the material which is to be procured versus that which is to be manufactured internally and the design for manufacture. From the top-level drawings and specifications, the details of the ship are progressively developed to the lowest level necessary for the fabrication of parts and pieces, sub-assembly of individual components (both hull parts and outfitting parts), assembly of hull units and final erection of these units on the ways. Figure 1-6 shows the development and progression of drawings.

Throughout the design development, detail planning and scheduling is performed by a consolidated group of design engineers, planners and production engineers. This planning is part of the design process in that an iterative cycle of design - planning - design occurs at each. level of drawing development. On the basis of the top-level design the hull is subdivided into major hull units suitable for handling, outfitting and erecting. Subsequently, each unit is further divided into its detailed parts which are identified on material lists for either procurement or manufacture. Design engineers progressively detail each level of the ship breakdown in drawings of units, sub-assemblies of hull and outfitting components and detail parts and pieces.

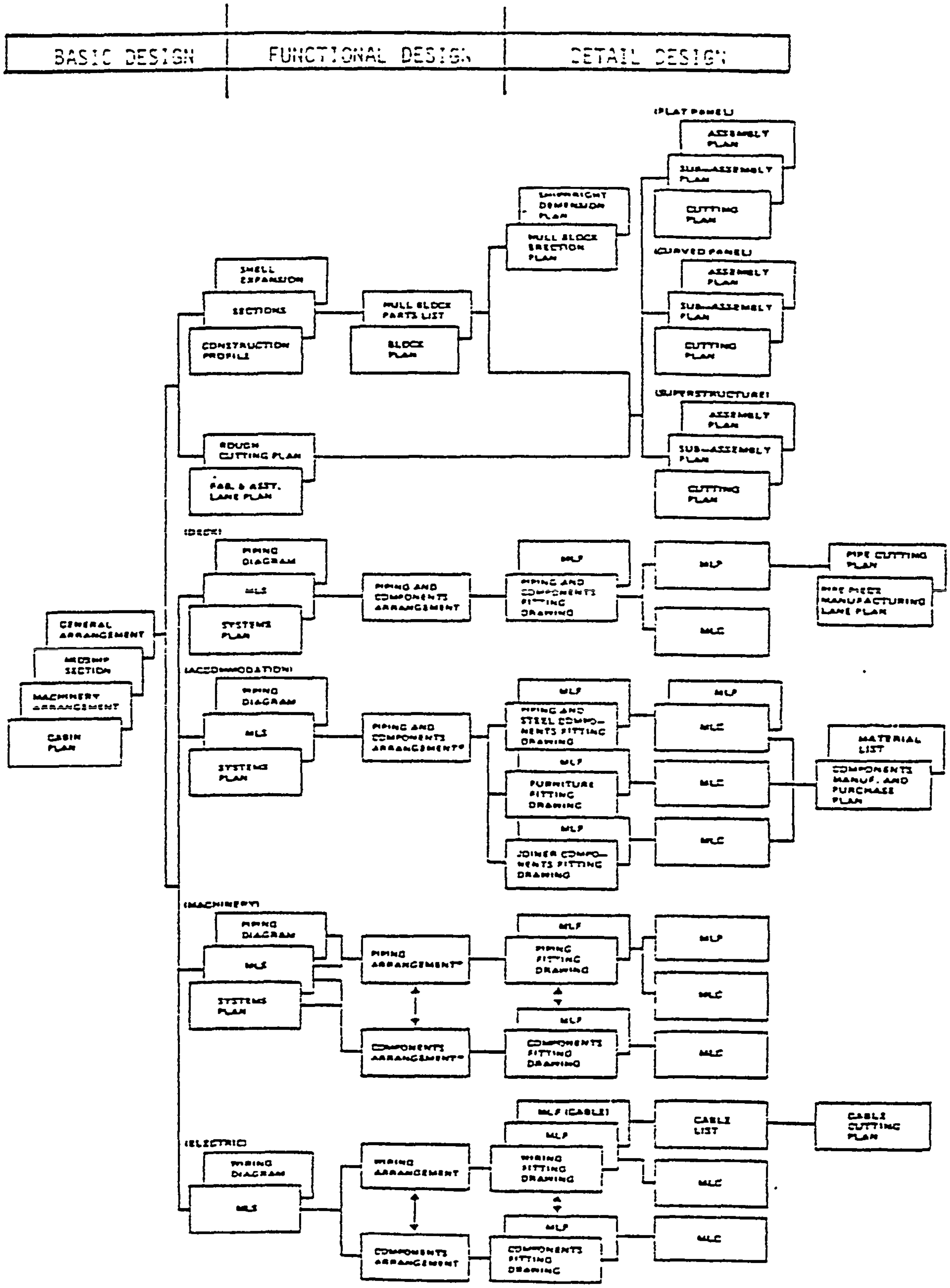



FIGURE 1-6

DESIGN DEVELOPMENT

As part of the planning/detail design development process, a series of planning documents are developed. Detailed assembly procedures are documented for each unit in Assembly Specification Plans and a series of Working Instruction Plans provide data relevant to: Marking, Cutting and Bending of plates during fabrication; Unit Parts Lists, Finish Dimension Plans for each unit; Sub-assembly Plans: Assembly Plans; Assembly Jig Size Lists; and Lifting Instruction for each unit. Working Instruction Plans are also prepared for specific elements of the erection process, such as: the Unit Arrangements Plan; Shipwright Dimensions Plan; Support Block Arrangements Plan; Welding Instructions; and a Scaffolding Arrangements Plan.

Simultaneously with the design development and production planning, Accuracy Control Engineers designate the critical dimensions of the procured and manufactured components and units to assure the highest accuracy of the product at each stage of production. This Accuracy Control activity greatly influences the design and the selection of the production processes to be utilized. Figure 1-7 depicts the concept of Accuracy Control in IHI.

Throughout this design process Production Planning and Engineering personnel attached to each of the Panel, Hull and Outfitting Workshops, provide appropriate production information and requirements to the designers. The working drawings and plans are carefully prepared to closely match facility and production organization capabilities.

## OUTFITTING ENGINEERING

### Design and Material Listing

The basic design planning for outfitting occurs during the evolution of the Basic Design into the detail working drawings. Subsequent

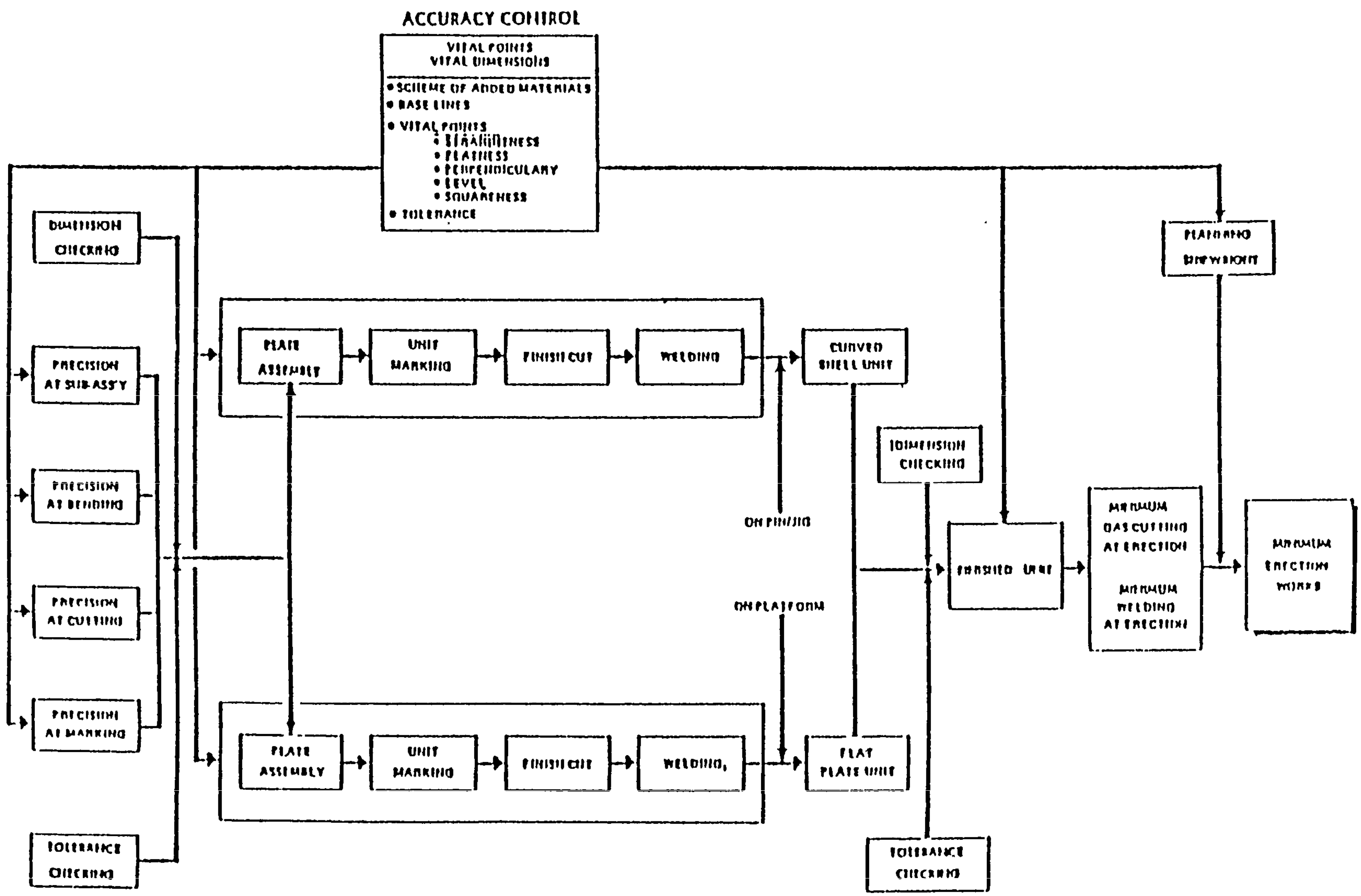



FIGURE 1-7

CONCEPT OF ACCURACY CONTROL IN IHI

to receipt of the Basic Design. the shipyard design department, in collaboration with the Fitting Workshop Production Planning and Engineering staff, develops system diagrams for each functional system of the ship. These diagrams do not reflect any sub-division of the ship into units. The diagrams do however, define all components required in each functional system. On the basis of these diagrams, a Material List by System (MLS) is compiled. These lists provide an itemization of the bulk and raw materials and system components required for a particular Material Ordering Zone. Figure 1-8 provides an example of an MLS.

IHI establishes a series of "Zones" for each ship: major zones, Which are primarily used for sub-dividing the ship for the purpose of hull construction; Material Ordering Zones, which are used to categorize material for procurement; Outfitting Zones, which designate major areas of outfitting; and, Outfitting Work Zones, which are further sub-divisions of Outfitting Zones into discrete small packages of outfitting work. Figure 1-9 illustrates these different types of zones.

The system diagrams developed by the Engineering Department are part of the second stage of design development which is called "Functional Design". This stage takes the Basic Design to the next logical level of development, i.e. Detail Design.

During the detail design stage the data from the functional design is converted into working drawings of unit assemblies, sub-assemblies, detail parts and pieces, etc. Also at the detail design stage an Outfitting Zone Plan is developed for the ship. An "Outfitting Zone" is simply a geographical area (3-dimensional) of the ship having no relation to a particular system. Instead, all systems within a given

MLS

# 番船別装置部品表

| 機装品コード MTL. CODE | 品名 DESCRIPTION / 材質、型式、規格、寸法 / 引当指示項目 | 取付符号 PIECE NO. | コード | 単位 | NO. 数量 (NET) / 数量 (GROSS) | WT 重量 (NET) / 重量 (NET) | 引当図番 | 手配区画 SUB ZONE | 備考 |
|---|---|---|---|---|---|---|---|---|---|
| 403002015 | FC ANGLE VALVE | 33,10,00 | | | 1 | 104 | | | 98 |
| | FC/BC FL 5200B | | | | | | | 14X171---( | 10391 |
| | | R/042V | A32 | 1 | 1 | 104 | | 14X171---( | 0000 |
| 403002015 | FC ANGLE VALVE | 33,10,00 | | | 1 | 104 | | | 98 |
| | FC/BC FL 5200B | | | | | | | 14X171---( | 10391 |
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| | ** SUB-TOTAL | ** | | 10 | | 1040 | | | |
| 403003008 | FC S.D.C.GLOBE VALVE | 31,30,00 | | | 1 | 14 | | | 98 |
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| | ** SUB-TOTAL | ** | | 1 | | 14 | | | |
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| | 922348 362902 | O-019V | A32 | 1 | 1 | 21 | | 14X110---( | 0800 |
| 403003009 | ** SUB-TOTAL | ** | | 1 | | | | 14 | |
| | ** SUB-TOTAL | ** | | 1 | | 21 | | | |
| 403003010 | FC S.D.C.GLOBE VALVE | 33,10,00 | | | 1 | 27 | | | |
| | FC/BC FN 5080GB | | | | | | | 14XH3AP--( | |
| | 922367 364901 | R-201V | A32 | 1 | 1 | 27 | | 14XH3AP--( | 0800 |

(2205)

2262 2681 14030000 80年 3月12日 P. 155

FIGURE 1-8

MATERIAL LIST BY SYSTEM

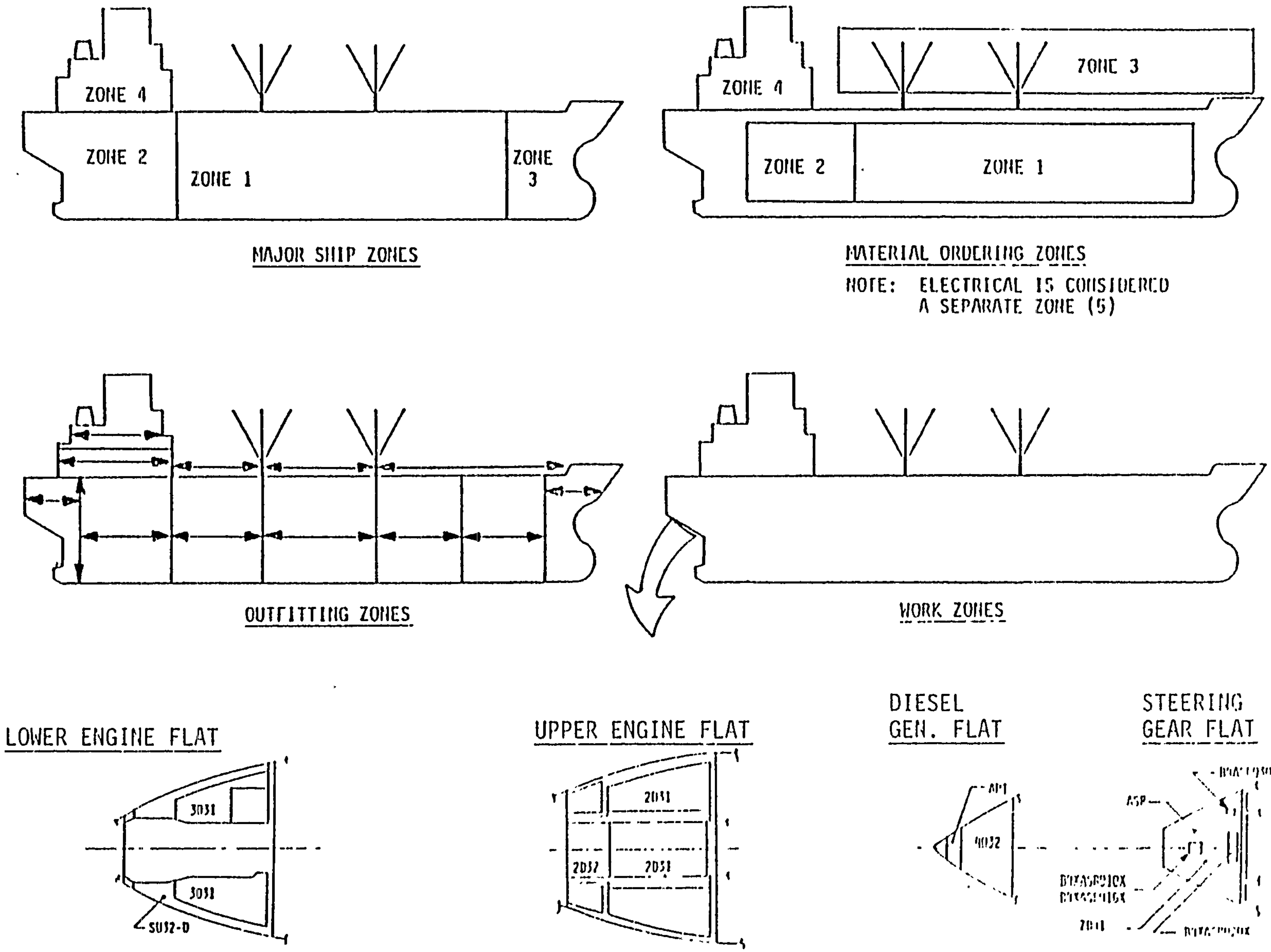


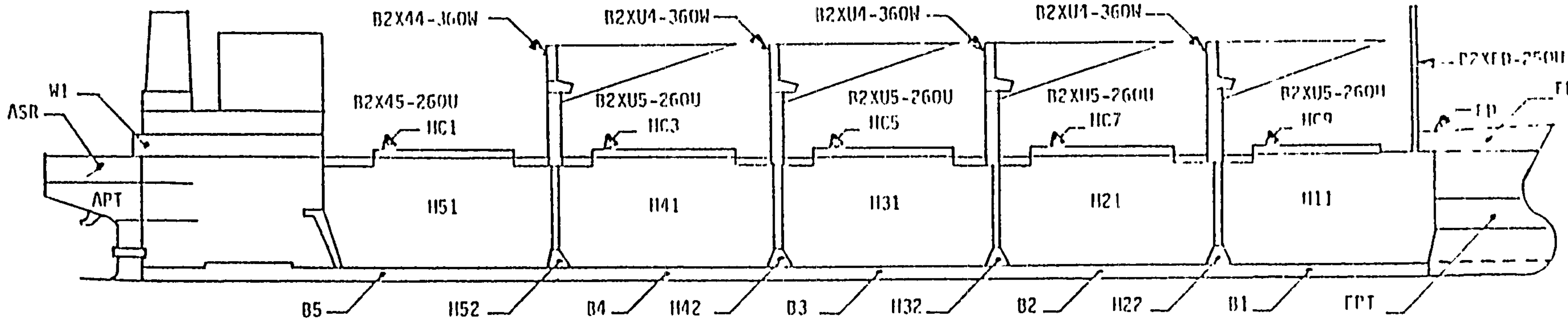

FIGURE 1-9 DIFFERENT SHIP ZONES

area are encompassed by the zone boundaries. Figure 1-10 illustrates the Outfitting Zones identified for one type of ship.

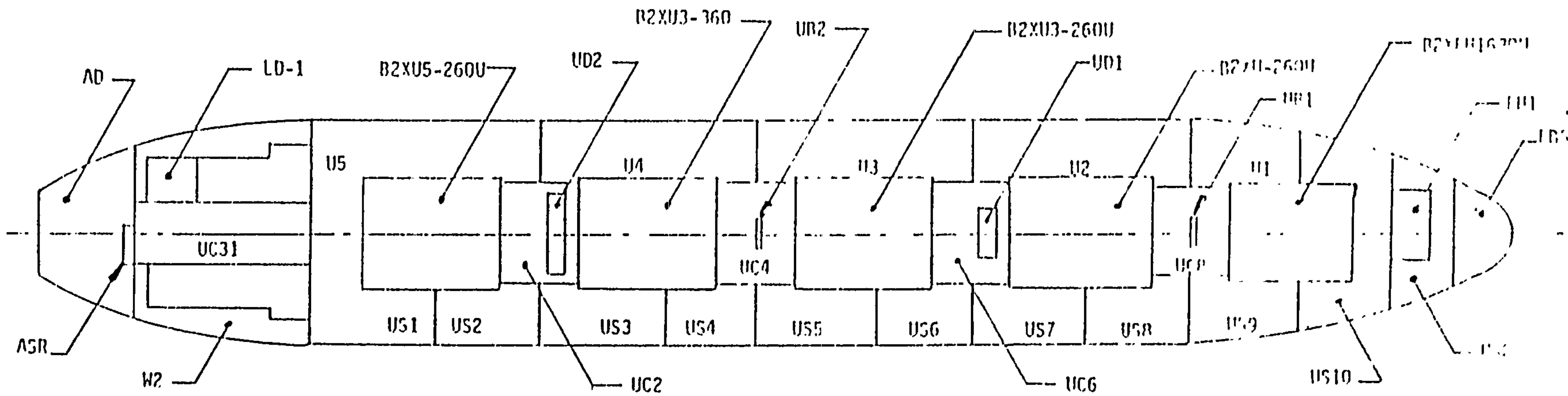
With the identification and designation of Outfitting Zones. detailed material lists are formulated together with piece drawings for the manufacture of pipe pieces, piping arrangements, and outfitting pieces and sub-assemblies. Specific material lists are prepared for the manufacture of pipe (Material List for Pipe - MLP) and for other outfitting components (Material List for Components - MLC). These material lists and the associated piece drawings are eventually scheduled for production through the yard pipe or fabrication shops. Figures 1-11 and 1-12 present examples of these material lists.

In addition to the above, the detail design effort also produces composite drawings showing the layout of all outfitting material in specific "Work Zones" (a further breakdown of the outfitting zones into small packages of outfitting work). These composite drawings show the interrelationship of the many different systems integral to the individual work zones together with details of mounting and joining. Figure 1-13 provides an example of a composite drawing. (The composite drawing system will be further explained in subsequent paragraphs.)

Upon completion of the composite drawings, the final stage of design, Work Instruction Design, is initiated. This design stage produces drawings of outfitting components which are to be installed at different production stages, e.g. sub-assembly, assembly, erection, and after launch. Figure 1-14 illustrates this development from top-level design data to individual Work Instruction Drawings. Accompanying these drawings is another material list, the Material List for Fitting (MLF) which corresponds to the work to be accomplished at the production




FORE SECTION




UPPER DECK

FIGURE 1-10

OUTFITTING ZONES

# MATERIAL LIST FOR PIPE

MLP

| DESCRIPTION | S NO | OUTFITTING CODE | C NO | MATERIAL CODE | | | | | | WEIGHT |
|---|---|---|---|---|---|---|---|---|---|---|
| 15A | | | 94 | 161001 | 1 | | | 13 | 0 | 93.7 |
| 25A | | | 94 | 161003 | 1 | | | 31 | 0 | 414.3 |
| 40A | | | 94 | 161005 | 1 | | | 25 | 0 | 556.3 |
| 50A | | | 94 | 161006 | 1 | | | 14 | 0 | 408.9 |
| 65A | | | 94 | 161007 | 1 | | | 9 | 0 | 369.8 |
| 15B | | | 94 | 162001 | 1 | | | 1 | 0 | 7.2 |
| 25B | | | 94 | 162003 | 1 | | | 9 | 0 | 127.2 |
| 40B | | | 94 | 162005 | 1 | | | 14 | 0 | 315.7 |
| 65B | | | 94 | 162007 | 1 | | | 5 | 0 | 250.8 |
| 25C | | | 94 | 162103 | 1 | | | 1 | 0 | 18.0 |
| 40C | | | 94 | 162105 | 1 | | | 6 | 0 | 180.5 |
| 50C | | | 94 | 162106 | 1 | | | 4 | 0 | 164.1 |
| 65C | | | 94 | 162107 | 1 | | | 3 | 0 | 193.0 |
| 25CC | | | 94 | 162118 | 1 | | | 1 | 0 | 18.0 |
| 40BB | | | 94 | 162156 | 1 | | | 2 | 0 | 45.1 |
| 50BB | | | 94 | 162157 | 1 | | | 2 | 0 | 59.8 |
| 65BB | | | 94 | 162158 | 1 | | | 1 | 0 | 50.2 |
| 25CC NK | | | 94 | 172022 | 1 | | | 2 | 0 | 35.0 |
| 40CC NK | | | 94 | 172024 | 1 | | | 3 | 0 | 90.3 |
| 40CC AB | | | 94 | 178024 | 1 | | | 1 | 0 | 30.1 |
| 40SC LR | | | 94 | 184077 | 1 | | | 1 | 0 | 30.1 |
| 15B AB | | | 94 | 188004 | 1 | | | 1 | 0 | 7.2 |
| 25B NK | | | 94 | 182006 | 1 | | | 2 | 0 | 29.3 |
| | | | 94 | | | | | | | |
| | | | 94 | | | | | | | |
| | | | 94 | | | | | | | |
| | | TOTAL | 94 | | | | | | | 3,499.6 |

FIGURE 1-11

MATERIAL LIST FOR PIPE

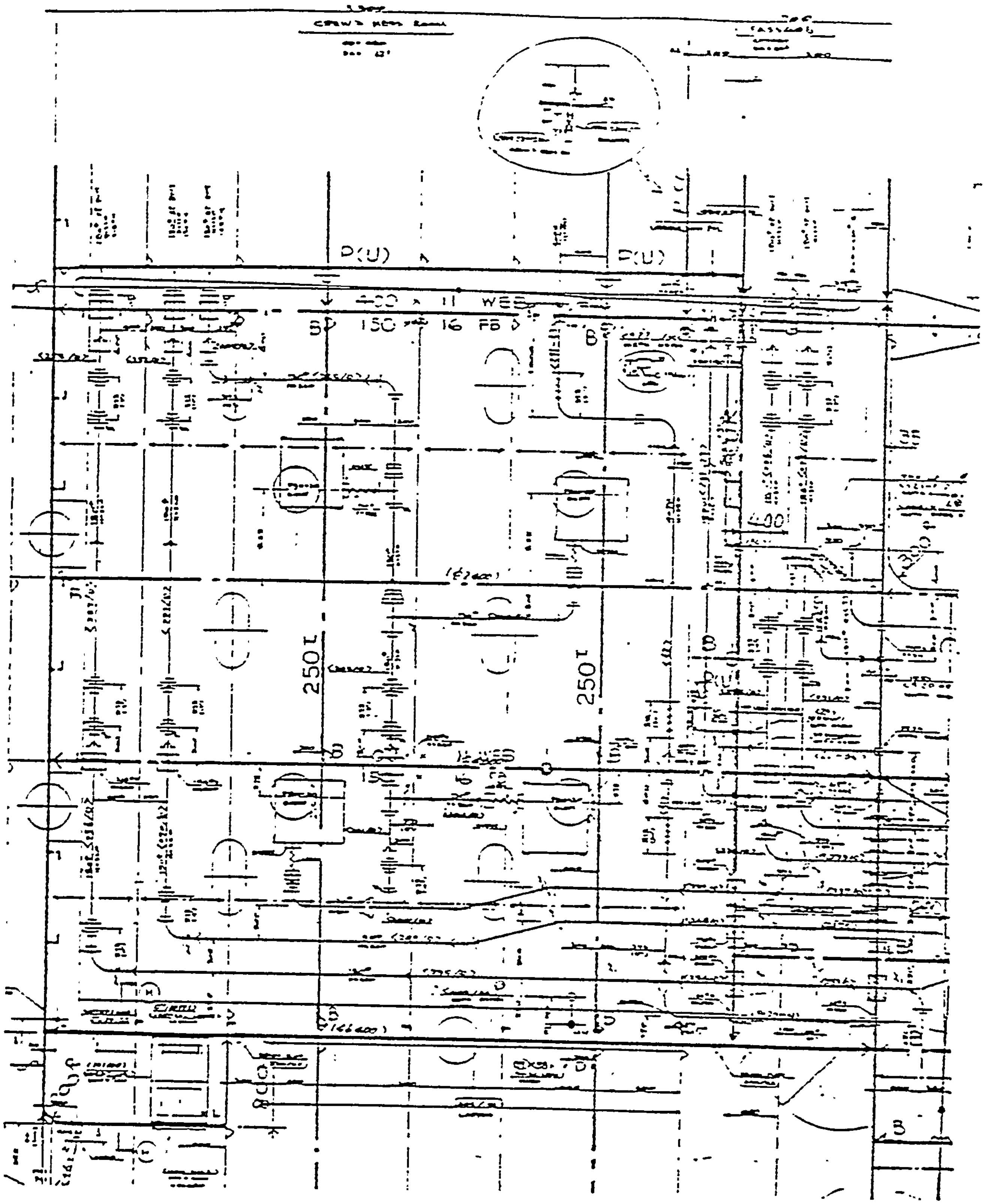



FIGURE 1-13

COMPOSITE DRAWING

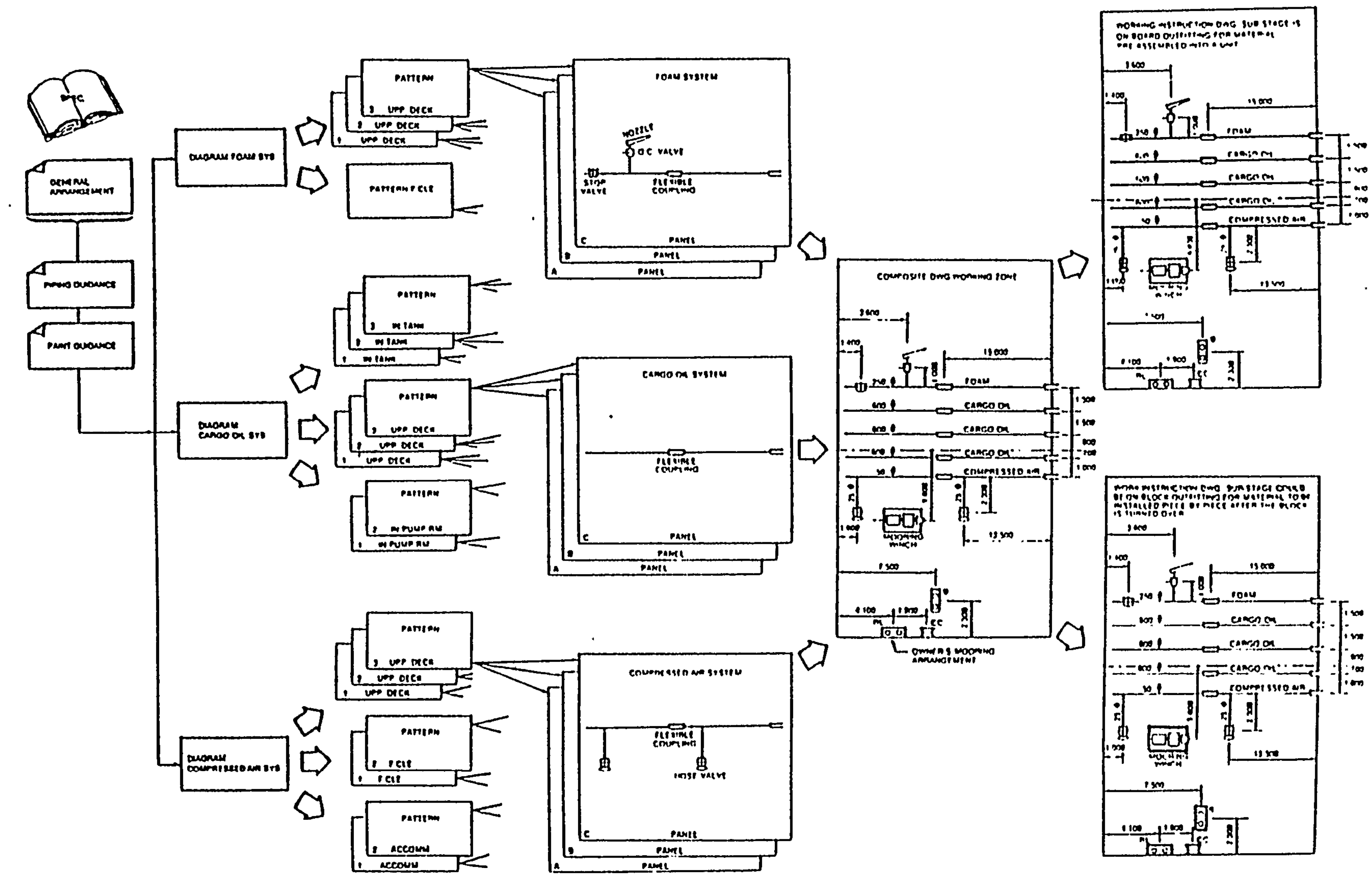



FIGURE 1-14

OUTFITTING DESIGN DEVELOPMENT

stage shown on the Work Instruction Drawing. Figures 1-15 and 1-16 provide examples of a Work Instruction Drawing and a Material List for Fitting, respectively.

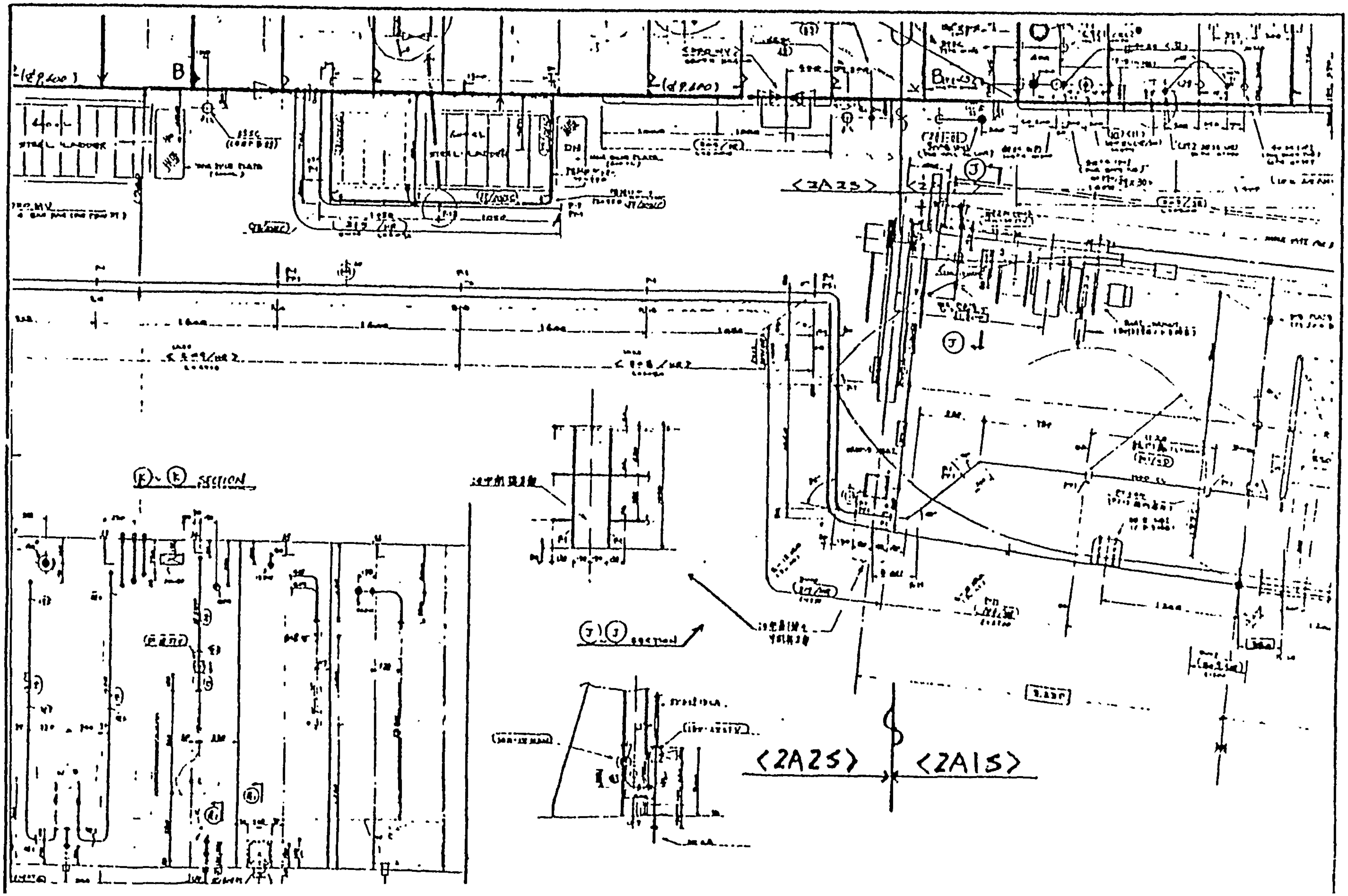
The Work Instruction Drawing, the associated MLF, the procured components and the manufactured components (i.e. by the yard) comprise a specific work package or "pallet" as it is identified by IHI. The "pallets" of information and material correspond to the "work zones" established for a given outfitting zone.

Composite Drawing System

In IHI composite drawings are the primary source of information for the pre-outfitting of entire zones of a ship. Another name for the composite drawing system is the compartment outfitting method. All outfitting systems are shown in an outfitting arrangement drawing based on a compartment or zone of the vessel. This is in contrast to the system by system approach, which usually shows one or more entire piping system for a major portion of the hull, or event for the entire vessel.

IHI has realized many benefits from the use of composite drawings for outfitting, especially in the important area of piping. Through a coordinator between outfitting design sections, all interferences are dealt with on a day to day basis. The composite drawings are prepared to a drawing supply schedule which is relatively standard for a basic vessel type. As nearly as possible, all outfitting sections simultaneously work on drawings for the same area of the ship.

A Design Procedure and Drawing Supply Schedule, considered a management standard, provides enough lead time before actual start of fabrication for the necessary design and engineering work that must


STEEL LADDER
STEEL LADDER
<2A2S>
K-K SECTION
J-J SECTION
<2A2S>
<2A1S>

A : Information for unit assembly
F : Fabrication sign.
L : Temporary location sign for next stage
U : unit of quantity
W : Indication of weight

# M L F

| Date |
|---|
| 19. 05. 11 |

| DESCRIPTION | Piece No | Specifications | Qty | Weight | Paint | Ref Dwg No / MLF No for TLM | Mtl code | Remarks |
|---|---|---|---|---|---|---|---|---|
| BUTTERFLY VALVE(MANUAL) | SW-425V | FC25 SCS13 5K ϕ 200 | 1 | 24 | D4 | N4044000 | 1404490000 | ♦ |
| BUTTERFLY VALVE(MANUAL) | SW-426V | FC25 SCS13 5K ϕ 200 | 1 | 24 | D4 | N4044000 | 1404490000 | ♦ |
| BUTTERFLY VALVE(MANUAL) | SW-472V | FC25 SCS13 5K ϕ 125 | 1 | 14 | D4 | N4044000A | 1404490000 | ♦ |
| BLIND FLANGE SS41 GALV.F8 5K 80SSC | | | 1 | 2 | R4 | | 4406910130 A | ♦ |
| WATER FILTER | SW-403S | 5K-200C (200X250) FIREGS | 1 | 141 | D4 | N408240C | 1408250900 | ♦ |
| WATER FILTER | SW-404S | 5K-200C (200X250) FIREGS | 1 | 141 | D4 | N408240C | 1408250900 | ♦ |
| FIRE & G S PUMP | MA-057AA | VEC 180/300M3/H ϕ 80/35M | 1 | 1000 | | N4451160A | 1445116000 | ♦ |
| FIRE & G S PUMP | MA-057AB | VEC 180/300M3/H ϕ 80/35M | 1 | 1000 | | N4451160A | 1445116000 | ♦ |
| MOTOR (FIRE & G S P) | P/FGR-M | 75KW 1800RPM TE V 0 | 2 | 1320 | | N445117 | 1445117000 | ♦ |
| PIPE BAND SUPPORT | | N=24 | 1 | 187 | | F 4634803 | 2463400000 | ♦ |
| ORIFICE | SW-401W | 10K ϕ 125 | 1 | 9 | D4 | N469930E | 1469930000 | ♦ |
| ORIFICE | SW-402W | 10K ϕ 125 (D=39) | 1 | 0 | N01 | N469930D | 1469530000 | ♦ |
| VERTICAL LADDER | NG-100V | VFS-5 L/800 | 1 | 11 | D3 | F 4830212 | 2488620000 | ♦ |
| VERTICAL LADDER | NG-101V | VFS-5 L/950 | 1 | 13 | D3 | F 4830212 | 2483620000 | ♦ |
| FLOOR & GRATING | NG-010C | | 1 | 90 | | F 483101 | 2483100000 | ♦ |

| S. No | MLF - No | Req date | next stage | Work Dwg No | Shop | | PC length | Total wt. | Contrd wt | Erect wt | Pac |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2688 | 45Y057 | 19 06 01 | 14PS315-0 | 1U01 -3 | 7 | 42 PHQ.226 | | 785 / 5171 | 785 / 5171 | 785 / 5171 | 3 |

FIGURE 1-16

MATERIAL LIST FOR FITTING

precede the actual fabrication, assembly, erection and outfitting activities.

Concurrent with the preparation of the composite drawings, the material lists (MLF and MLP) are prepared. The MLF facilitates material gathering in advance of fitting. It corresponds to the fitting drawing which shows all material in a compartment or work zone. All outfitting pieces are numbered designating the compartment, system, and whether the parts are to be fitted on-unit or on-board. On-unit or on-board fitting designation may be made with a separate drawing (see Figure 1-17).

For all information necessary to fabricate pipes, separate pipe piece drawings are made. Piece drawings are actually breakdowns of a composite drawing showing each piece and fitting. A material list (MLP) is included on the piece drawing to show size, type, quantity, and material specification. This type of drawing is usually a three-dimensional view. Figure 1-18 provides an example of the kind of pipe piece drawing used by IHI.

The drawing package that is ultimately given to Production consists of the composite or compartment drawing, the fitting drawing, work instruction drawings and the MLF. In the production process, the foremen use the composite for reference, whereas, the workmen rely on the fitting drawings, the work instruction drawings, and the MLF.

## ADDITIONAL DESIGN AND ENGINEERING PLANNING

The Hull Construction and Outfit Planning discussed in the foregoing pages combine the aspects of design and production into a thoroughly defined set of working drawings and plans necessary for the

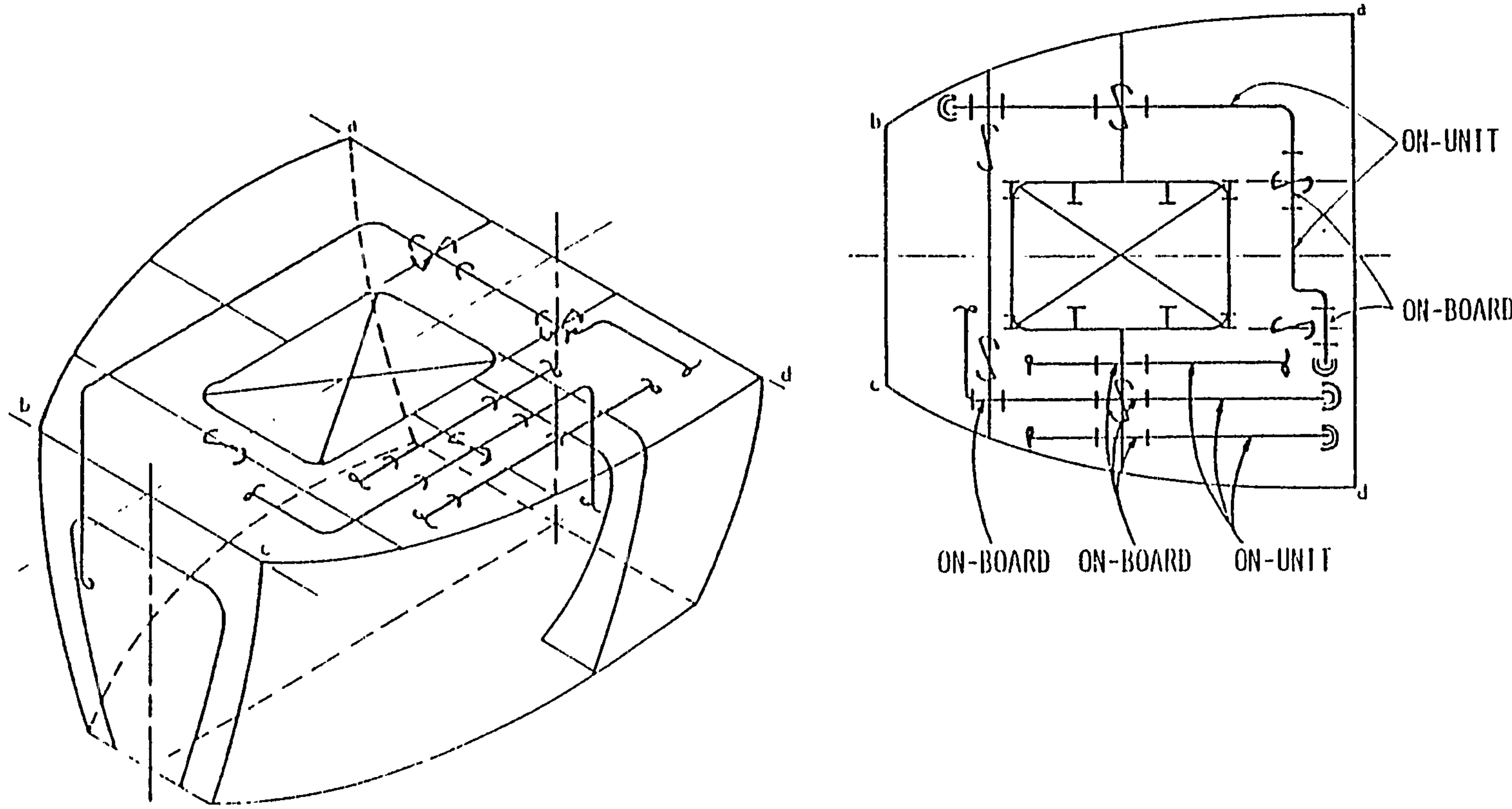
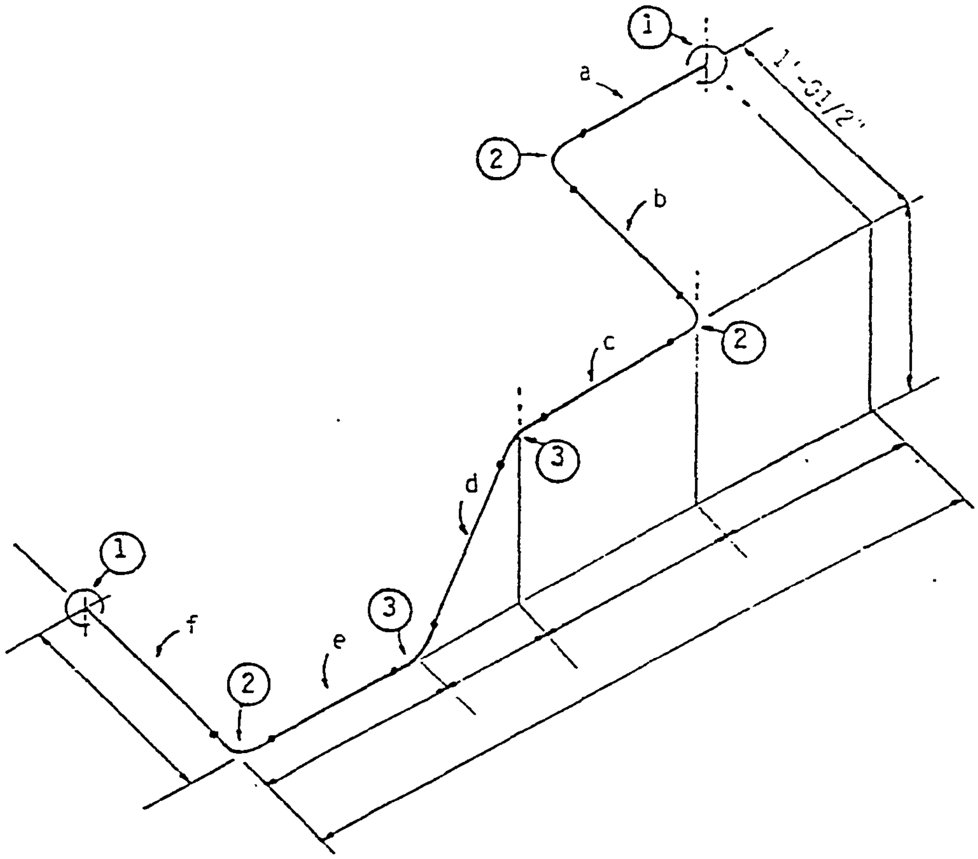



FIGURE 1-17

EXAMPLE OF DRAWING FOR DESIGNATION OF ON-UNIT OR ON-BOARD FITTING




MATERIAL LIST

| QTY. | DESCRIPTION | MAT'L | PC. MK. RESULTS |
|---|---|---|---|
| 2 | 3" 150# Flg | FS | 1 FF |
| 2 | 3" 45° Ell Sch 40 | BLK | 3 BW |
| 3 | 3" 90° Ell Sch 40 | BLK | 2 LR BW |
| 1 | 3" Sch 40 Pipe 2'1-1/8" | BLK | a |
| 1 | 3" Sch 40 Pipe 0'3-1/2" | BLK | b |
| 1 | 3" Sch 40 Pipe 3'9-1/2" | BLK | c |
| 1 | 3" Sch 40 Pipe 3'0-1/16" | BLK | d |
| 1 | 3" Sch 40 Pipe 0'5-9/16" | BLK | e |
| 1 | 3" Sch 40 Pipe 0'2-3/8" | BLK | f |

FIGURE 1-18

EXAMPLE OF PIPE PIECE DRAWING

(WITHOUT DIMENSIONS)

manufacture of the hull assembly units, the outfitting of those unit; and the erection and outfitting of the entire ship. This discussion has purposely omitted some types of planning (that occur simultaneously) in order to simplify the design process. However, it is important to cover these other planning aspects to complete the overview of this involved process.

Other plans are prepared by workshop engineering personnel to detail the methods for facilitating work during the erection stage and during on-board outfitting. This planning is called "Field Planning" and consists of the following types of plans:

Plan for temporary holes (in the hull during erection)

Plan for ventilation &-cooling of the hull on the ways

Plan for supply of electrical power and gas lines

Plan for stools arrangement on the ways

Plan for equipment access on-board and on working staging

Plan for standard shipwrighting techniques

Plan for maintaining shaft alignment considering the initial hogging of the aft and forward ship sections

Plan for tank arrangement and testing

Plan for final dimension check items

Plan for disposal of temporary pieces for construction

DESIGN CHANGE CONTROL

System design changes occur because of regulatory body requirements, owner requirements, builder changes due to design changes or errors, builder changes due to production errors or methods changes, or vendor changes because of errors in drawing, changes in material or equipment, etc.

In IHI, the system for design change is initiated in the design department, regardless of the source of the change. In order to minimize rework and rescheduling, preliminary information regarding the change is accomplished quickly. To facilitate smooth incorporation of the design change into the total system, changes that have a big influence on schedule are dealt with at meetings held for the specific purpose of discussing design changes. On big items of change having effect on future vessels, information will be fed back into the design process.

The preliminary information system is immediately effected so that the change can be ordered to production before any rework is necessary. The formal information system is then effected to update all records and make all necessary notifications (refer to Figure 1-19). Thus, quick action to minimize cost and formal action to keep all records accurate are the two main objectives of the design change control system at IHI.

In the IHI Computer System (IHICS) for hull design, all design changes are quickly fed back into the system to minimize the negative effects of the change. The program is designed so that production corrections caused by design changes are minimized. Actual generation of physical data of parts can be postponed up to the execution of parts generation.

ENGINEERING ACTIVITIES--LAUNCHING TO DELIVERY

As is typical of practically all shipyards,-the Shipyard Design Department is involved as an aid to Production during the time from launching through delivery of the vessel. Some of the main activities are:

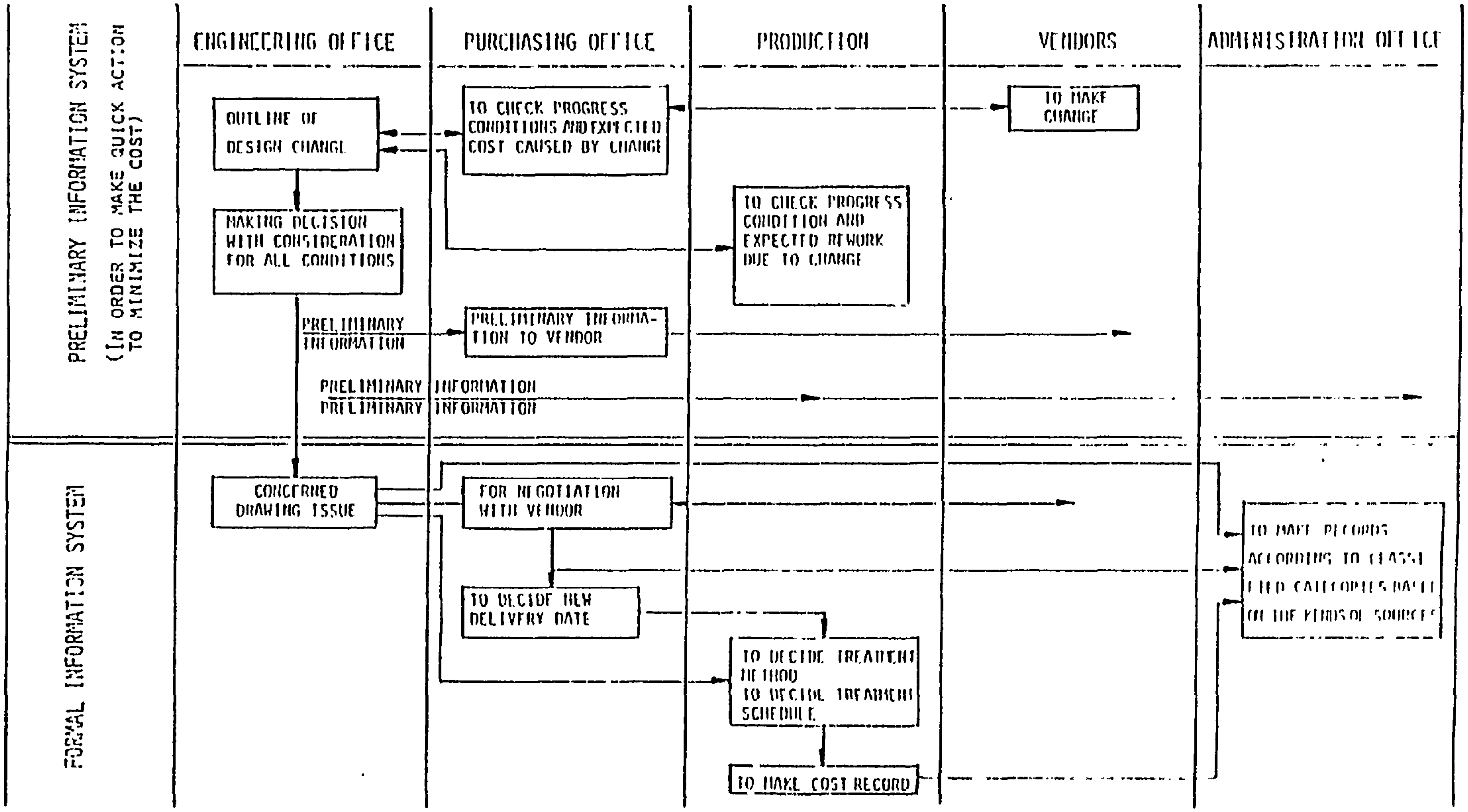



FIGURE 1-19

INFORMATION FLOW FOR DESIGN CHANGE

Launching

Incline Tests

Deadweight Measurement (Ship's Light Weight)

Plan of Equipment Testing and Sea Trials

Performance Confirmation

Ship's Operation Manuals

Finish Drawings to Reflect All Modification (Ship's Copy)

Provide Gross Tonnage Data According to Worldwide Requirements

## COMPUTER AIDED DESIGN

Since IHI entered the field of computer aided ship design and manufacture, several main systems have been developed and extensively utilized at the IHI yards. These systems have applications throughout the design and production processes beginning with the Basic Design at the Head Office in Tokyo through the development of the Key Plans and the Yard Plans at the shipyard. These main systems are the result of breaking down the engineering work to be done into simple processes. This process definition facilitated the building up of program modules which perform the necessary data processing according to the type of work to be done and the required output. In this manner, the IHI computerization group has developed an integrated system of design oriented programs that share a common data base but perform independently to provide the data necessary for all phases of ship design and automated fabrication.

Computerization is relied upon in the Basic Design stage to perform structural analysis, propulsion performance analysis and maneuverability analysis. As the design progresses toward development of the Key Plans, all necessary ship's calculations for naval architectural data are also performed. As the Key Plans are finalized and the Yard Plans are begun, the Hull Design system is fully utilized from the fairing of ship's lines to hull piece design. Systems for outfitting design are also employed.

Production Engineering and Material management also rely on computerized systems. Purchasing and issuing material are functions of the Steel Plate Control System. There is also a Material Control System for new ship construction. The design oriented functions for Production Engineering are for Hull Piece Drawing, Nesting of Hull Plates, Hull Piece/Parts Control System and a Pipe Processing plan.

Scheduling and manufacturing utilize computerization for Hull Construction Scheduling, Outfitting Scheduling, Manhour Calculation, N/C (Numerical Control) High Speed Marking System, N/C Gas Cutting System, and N/C Frame Bending and Pipe Bending.

MAIN IHI SYSTEMS FOR COMPUTER AIDED DESIGN

IHICS, or Integrated Hull Information Control System, is a series of program packages which assists engineers in the fields of design and production engineering for hull construction, and also provides information necessary for production.

IHICS resulted from the necessity to standardize as much design data as possible and to correlate these data with the established production processes of the IHI shipyards. IHICS provides the following:

Generation of engineering and production data from a small volume of input data prepared by engineers.

Assistance to engineers in design and production engineering activities.

Creation of a data base which supplies the manufacturing division with production engineering data, numerical control data and piece lists for-each stage of production.

IHICS is composed of the following three sub-systems: Basic Data Creation, Section Design and Production Engineering. Figure 1-20 describes these sub-systems in terms of their respective component programs in relation to the data base. Each of the program's functions are outlined in Table T1-4 which also outlines the program outputs.

COMPUTER AIDED DESIGN SYSTEM FOR PIPING

At IHI, computer aided design is utilized in the outfitting of vessels. Piping systems are automatically designed by the CADS system which is capable of designing new piping modules and modification of these modules when necessary. In addition to the automatically designed modules, the CADS system allows for input of manually drafted sketches of piping systems which will be processed and finalized as a usable design.

The basic flow of information into and from the CADS piping design system is outlined in Figure 1-21.

Figure 1-22 describes the process flow of piping design from basic design and functional design through drawing preparation for engineering and production.

Figure 1-23 illustrates the relationship of the CADS system in the preparation of detail piping design. As the transition from functional design to detail design is made, utilization of the CADS system begins. Both manually and automatically prepared data are processed by CADS.

Outputs of the CADS system utilize hull structure drawings to identify obstacles and interferences for piping. Main hull structures such as frames, longitudinals and decks are registered and drawn by the system. Three part drawings of piping plans show plan, side and

| SUB-SYSTEM | MODULE | - Component Programs | OUTPUTS |
|---|---|---|---|
| BASIC DATA CREATION | FAIRING | - Lines Fairing Program | *Geometry Data Base, Panel Data Base, Scantling Data Base<br>*Complete Drawing of any Desired Portion of Lines Drawing<br>*Book of Mold Loft Offsets<br>*Structural Body Plan (1/10, 1/50)<br>*Shell Expansion Plan<br>*Panel Plan (Deck, Bulkhead, Flat, etc.) |
| | SHELL LANDING | - Seam/Butt Landing Program<br>- Longitudinals Landing Program<br>- Scantling Definition Program | |
| | PANEL LANDING | - Seam/Butt Landing Program<br>- Longitudinal Landing Program<br>- Scantling Definition Program | |
| | 3-D PROCESS | - Panel Definition Program<br>- Compartment Definition Program<br>- Cut Plane Program<br>- Panel Composition | |
| SECTION DESIGN | SECTION DESIGN | - Web Figure Definition<br>- Stiffener & Joint Arrangement on Web | *Section Plan (1/10, 1/50)<br>*Piece Control Data List<br>- Piece List for each assembly unit<br>- Includes piece name, quantity , scantling, weight, piece drawing format, fabrication process and other production control data<br>- Facilities data correction |
| | SCANTLING DESIGN | - Web/Face Plate Scantling Definition<br>- Stiffener Scantling | |
| | SCANTLING DEFINITION | - Web/Face Plate Scantling Definition<br>- Stiffener Scantling | |
| | PIECE DATA ASSORTMENT | - Piece Data Assortment Program | |
| PRODUCTION ENGINEERING | EDITING PROGRAM | - Part Program Generator<br>- Plate Edge Modifier Program | *Piece Drawing (including Tabular Format)<br>*Numerical Control Data/Tape<br>*Piece List for each Stage of Production<br>*Template for Bending (Shell Plate and Longitudinal Frame)<br>*Unit Marking Data for Shell<br>*Jig Heights for Curved Shell Unit Assembly |
| | PART GENERATION | - Shell Plate Development and Assembling Data Calculation (SHELL)<br>- Longitudinal/Transverse Frame Development (LODACS)<br>- Internal Structure Development (Line System) | |
| | NESTING PROGRAM | - Manual Nesting Program<br>- Interactive Nesting Program by CADS<br>- Post Processor for Numerical Control Machines | |
| | PART DATA BASE ADMINISTRATION | - Part Data Base Handler<br>- Piece List Editing Program for:<br>*Fabrication<br>*Subassembly<br>*Assembly<br>*Erection | |

TABLE T1-4

COMPONENTS OF IHICS

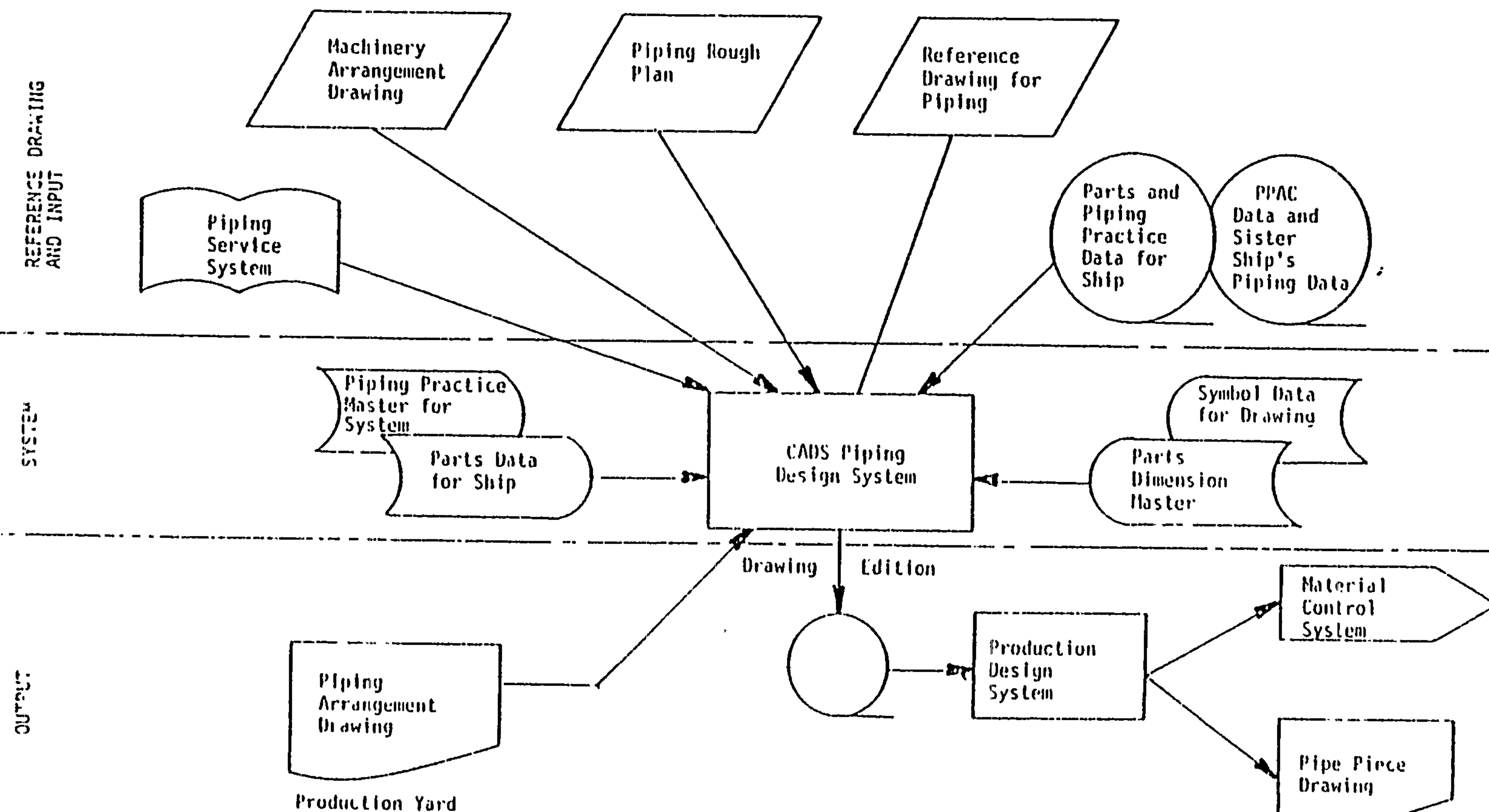



FIGURE 1-21

CADS OPERATION

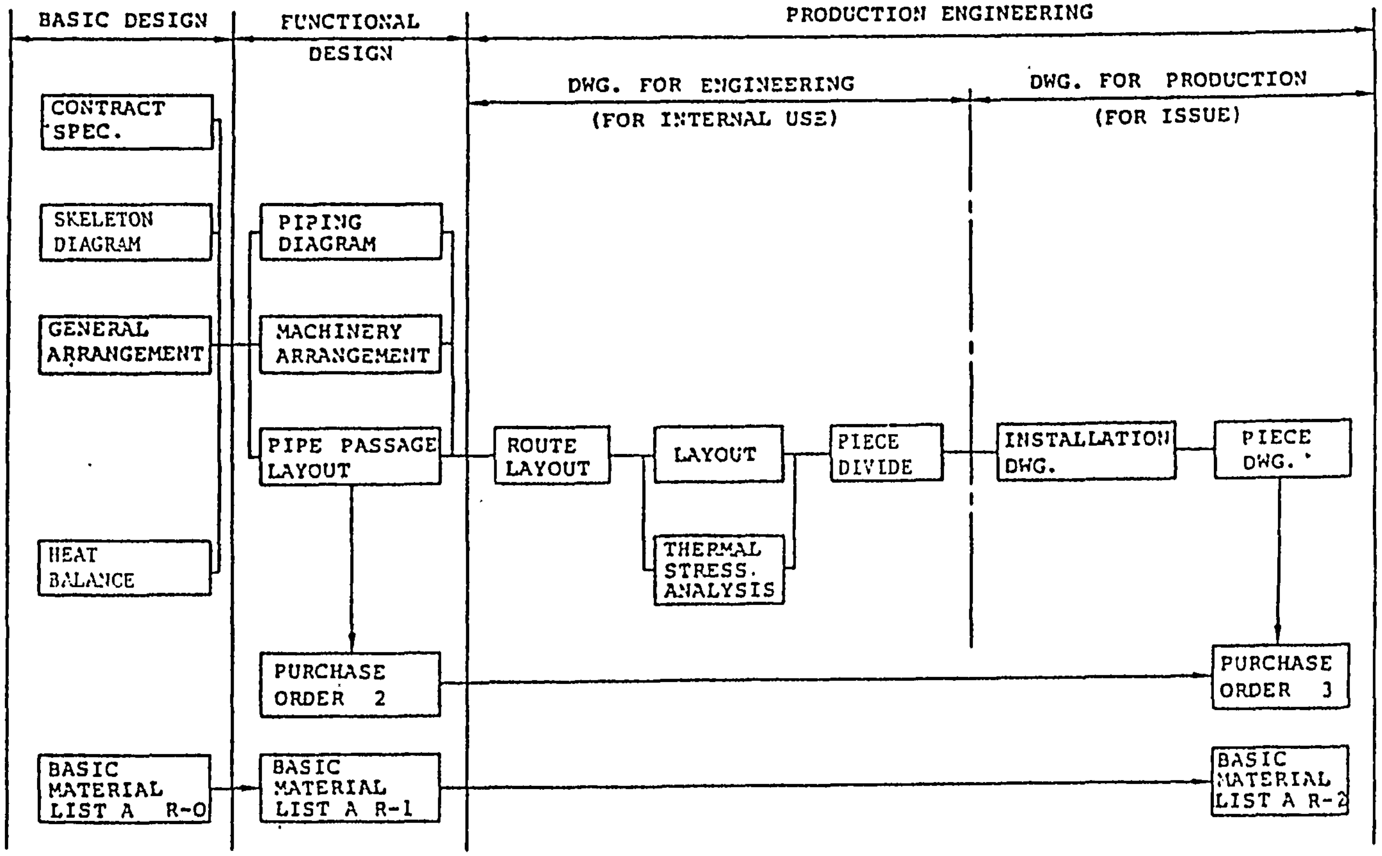



FIGURE 1-22

PROCESS OF PIPING DESIGN

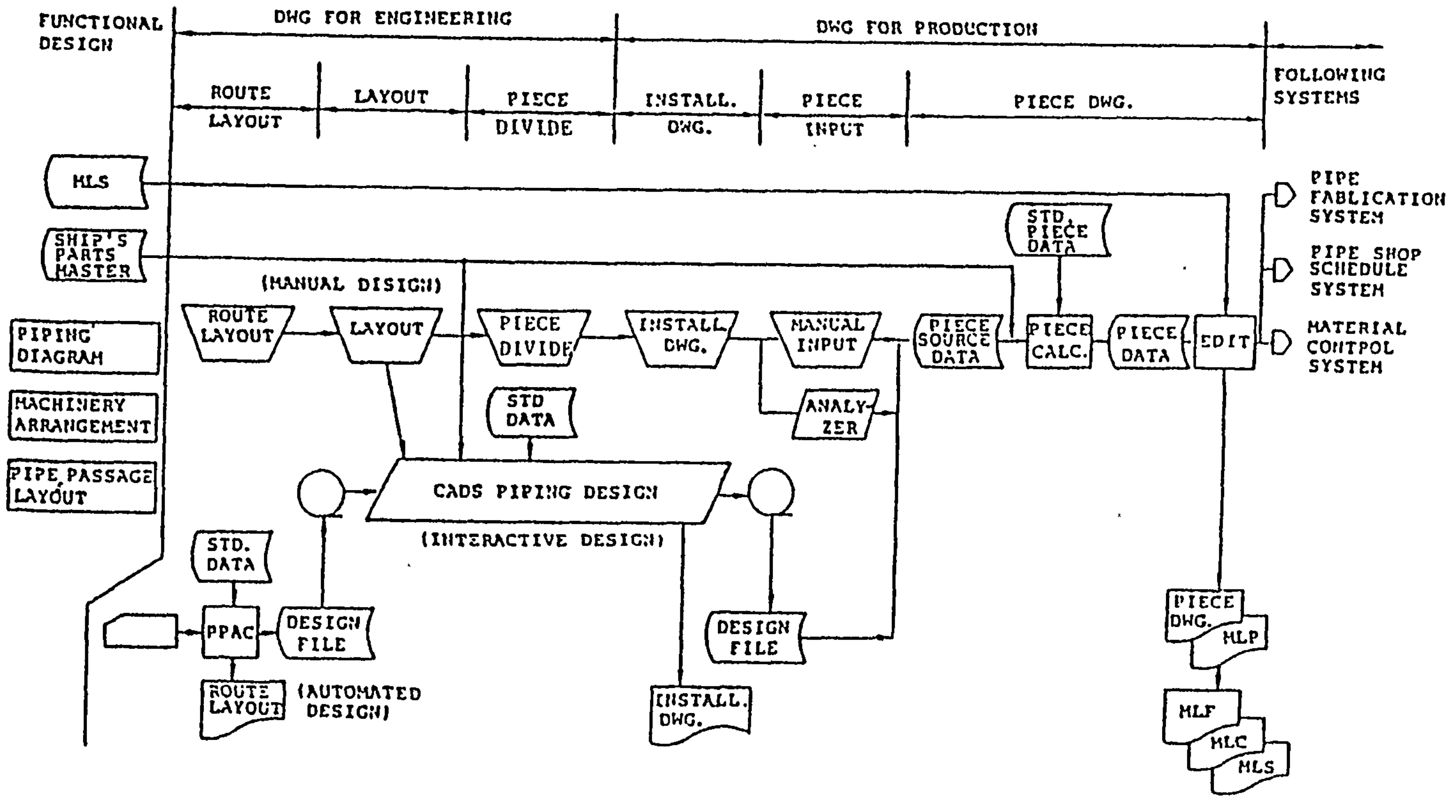



FIGURE 1-23

PIPING PRODUCTION ENGINEERING SYSTEM (ENG. RM) section view. Definition of piping runs is accomplished by indicating start and end points and bend points. Optional section drawings are available as outputs to show intersections of pipe with other structures such as tanks and bulkheads. Clearance between pipes is calculated automatically.

Other functions and characteristics of the CADS system are the setting of pipe fittings on a piping run, checking pipe piece dimensions based on fabrication standards, design of pipe support pieces, and providing data for the pipe piece fabrication system and the material control system.

NUMERICAL CONTROL STEEL FABRICATION

The design work for the hull involves the preparation of a rough structural drawing and a shell plate expansion drawing based on a typical midship section plan and a lines plan for a given vessel. Following this, detailed structural calculations are conducted and a detailed structural drawing is prepared. During these design processes, the data base is continually added to and updated. The result of this building up of the data base is a structural drawing produced by computer directed automatic drafting machines, plotters, and other graphic displays.

The preparation of structural drawings by computer points out the fact that the shapes of the various pieces are dealt with numerically. As part of the data base, these numerical data are directly tied in with the N/C (numerical control) marking and cutting equipment. The main result of this is omission of traditional mold loft practices with more automation of the production system.

At IHI, automation of many fabrication processes has led to more accurate and rapid fabrication of steel parts as well as creating more simplified jobs for the workers.

GAS CUTTING AT IHI

The philosophy and policies which affect numerical control steel fabrication in Japan's shipyards have evolved as a result of certain conditions prevalent in the Japanese shipbuilding industry. The abundance of highly skilled manpower, industry standards and highly developed facilities, among other conditions, have enabled the IHI yards to utilize N/C methods of fabrication without relying on them to perform jobs better suited to other types of equipment and methods.

IHI's alternative to old methods of mold lofting is the 1/10 scaled body plan lofting method. Large table automatic drafting machines provide high precision scaled drawings. These drawings are used for various fabrication methods including Electro Photo Marking and final checking before N/C burning. Full scale drawings of small parts such as collar plates and brackets are used as templates and to direct optical tracer burning equipment.

IHI PLATE MARKING TECHNIQUES

At IHI shipyards, plate marking is accomplished by several different processes all of which rely on N/C generated data. Selection of the marking method is made according to whether the marking will be done on a single plate or a panel that is composed of more than one plate having already been welded together.

In the case of panels, marking is done after welding to allow for neat cutting (to exact dimensions) of the panel. Steel tapes are prepared in the mold loft from tabular data and stored until required for manual marking.

For marking single plates, two main methods are applied, N/C plate marking and Electro Photo Marking (EPM). Selection of the method of marking is made with regard to leveling the workload of the yard's marking facilities and with consideration for smooth work flow.

A blend of optics and electronics, EPM is a rapid method of marking that can work a raw plate in about eight minutes. In a special dark room, the raw plate is positioned on rollers beneath a light projector that is equipped with a precision lens designed to enlarge a 1/10 scale image to full scale on the plate below.

The image that is projected is made of various 1/10 scale piece drawings produced on clear film by automatic drafting machines. These small drawings are nested on a large piece of clear film which is a 1/10 scale representation of the plate that is to be marked. All necessary material marks are manually added to this nesting drawing before it is placed in the projector so that when the EPM process is completed, all pieces will be completely marked.

Phototoner, a light sensitive powder charged with static electricity, is spread over the plate. The nested 1/10 scale drawing is then projected at full scale onto the plate. This step in the process causes the projected image to adhere to the plate. The precision of the printed pattern is accurate enough for the fabrication of hull pieces.

Numerical control plate marking is accomplished by burning zinc or plastic powder onto a plate to form a continuous 1/16" wide line. A

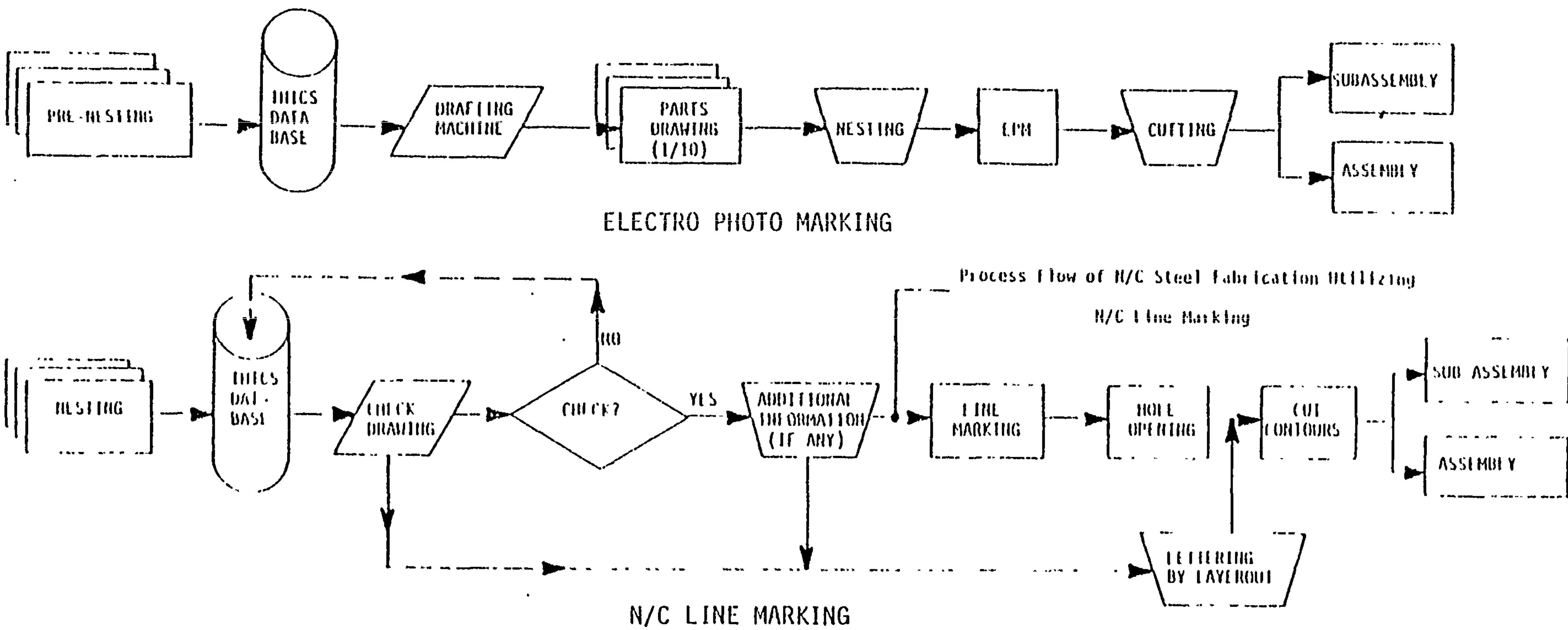



FIGURE 1-24

**PROCESS FLOW OF N/C STEEL FABRICATION UTILIZING ELECTRO PHOTO MARKING AND N/C LINE MARKING**

special burning torch equipped with a hopper/dispenser applies the powder to the plate just ahead of the moving torch. This method of line marking is capable of laying down a continuous line at the rate of forty feet per minute.

## LEVINGSTON SYSTEM AND APPLICATION OF IHI TECHNOLOGY

### APPLICATIONS OF IHI TECHNOLOGY

During the course of the Technology Transfer Program, Levingston has studied the IHI design and engineering systems and practices. The various studies entailed detailed analysis and comparisons which in most cases led to decisions for implementation of the IHI technology or methodology with modification if necessary, or to reject it after cost trade-off studies were applied.

In some cases, implementation of IHI technology in areas of the shipyard other than design and engineering has brought about the need to change certain design and engineering practices accordingly.

### Computer-aided-ship Design

In the area of computer-aided ship design, the IHI system and the SPADES system which is in use at Levingston were compared. Detailed documentation of both systems facilitated this comparison.

It was determined that both systems were relatively equal and there would be no need to change from SPADES to the IHI system. At that point the study concentrated on determining if full benefit from SPADES was being realized. All available SPADES modules were studied including those not in use at Levingston. A detailed comparison table of SPADES and the IHI system is provided in Appendix J of this report.

The conclusion to this study determined that both systems are very good shipbuilding tools, and while the IHI system is fully utilized to the best advantage of the IHI shipbuilding complex, SPADES at Levingston is somewhat limited by lack of implementation and facilities. It was determined, however, that SPADES may be better suited to Levingston's purposes and methods. For example, those SPADES modules that actually duplicate the old style lofting were better for Levingston because the input coding is easier and the data base is referenced by all of the SPADES modules, whereas in the IHI system some modules are of the "stand alone" type and require additional inputs.

Thus it was decided that implementation of the IHI system was not necessary and that as Levingston's requirements for computer-aided design software increased, SPADES could provide what is necessary.

<u>Numerical Control Steel Fabrication</u>

Some changes in Levingston's steel production methodology changed as a result of IHI's recommendations. In the area of bending and shaping steel plates for the shaped zones of the hull the IHI methodology for cold bending followed by flame bending (or line heating) was implemented. This created new demands upon the mold loft for providing special sight line templates necessary for this process. Of course, flame bending is only one step in the overall method of curved unit assembly used extensively at IHI. When this method of assembling large curved units on adjustable pin jigs was adopted still more demands were placed on the loft. In these cases, the SPADES system already provided enough data for preparing the necessary templates and for setting the heights of the pins of the adjustable jigs. It was only a matter of utilizing what was available.

In other areas of numerical control steel fabrication some deficiencies at Levingston were identified after comparison to the IHI methods and facilities. Because of various conditions present at Levingston, and also common to other U.S. shipyards, almost all lofting work was performed in the N/C loft and almost all plate was marked and burned by the N/C burning and marking machine. As an alternative to this practice of burning everything by N/C methods, another method of automatic burning has been installed in the form of a 1:1 optical-tracer burner director. This has lessened the load on the N/C burner considerably. A high speed parallel burner has also been installed for burning flat, straight plates.

Various other recommendations from IHI have also been implemented such as leveling of the workloads between the various processes for fabrication and rearrangement of shops and facilities.

## Zone Fitting and Composite Drawings

The IHI Methodology for outfitting a vessel involves Zone Outfitting and Palletization. These concepts provide benefits to the total system in terms of manhour savings, material management and personnel attitudes. However, more engineering time is required to support them.

Zone outfitting and the pre-outfitting of hull units prior to erection may do more than any other single aspect of IHI technology toward optimizing timely and profitable ship production. Therefore, whatever design and engineering methods, systems and practices are required for their implementation must be seriously considered.

Transformation to zone orientation begins with a hull unit arrangement or breakdown. The next step is preparation of composite drawings for outfitting according to the established three dimensional outfitting zones. These composites show zone boundaries and include all systems within that zone. Interferences between systems are recognized and eliminated during the preparation of these composite drawings.

Work Instruction Drawings and Material Lists

Further processing of the design is necessary for producing the working drawings to be used by Production. These drawings identify the area of the outfitting zone and the stage of the production sequence at which the work will be performed. For the hull, designations are made on assembly, sub-assembly and cutting plans. For outfitting, designations are made on work instruction drawings, each of which is developed with its own material lists for the on-board, on-unit or sub-assembly stages. This hierarchical sub-division continues by zone/area/stage with the preparation of the detail design drawings for pipe pieces and components other than pipe and their respective material lists.

It is in the manner described above that the engineering and planning process continues until each zone is broken down to a minimum level. The material lists also facilitate palletization, the IHI method of material management. The material lists for a specific zone/area/stage are used to gather the material and place the material in a physical pallet for shipment to the site at which that material will be installed. Such an organized material system facilitates rapid performance of outfitting tasks, whether they take place at the sub-assembly, on-unit or on-board stage.

## Automated Scaled Body Plan of Mold Lofting

From the early stages of the Technology Transfer Program IHI has recommended implementation of scaled body plan lofting. This system involves the installation of a large table automatic drafting machine in the mold loft and a drum type plotter/drafter in the hull section of the engineering department.

IHI uses the large drafting machine for making templates for the cutting, shaping and verification of parts. The high .accuracy and speed of the machine makes it possible to use its graphic output for directing optical tracer type burning equipment and for high efficiency electro photo marking equipment.

In the engineering department, the drum plotter calls upon the established data base for a ship and rapidly produces drawings that can be manually sectioned and detailed and actually used as working drawings.

The addition of both of these machines could result in significant manpower savings in the mold loft and the engineering department's drafting sections.

## Additional -Future Implementation

In addition to those specific areas of future implementation identified in the preceding paragraphs, other methods, systems and practices may become necessary at Levingston. As the production methodologies evolve and change, so must the practices of those functions that support this production. Design and engineering must provide what the total system requires and at the same time must be provided with the support and lead-time necessary to successfully perform those functions. .

# SECTION 2

# PLANNING & PRODUCTION CONTROL

## SECTION 2

## PLANNING & PRODUCTION CONTROL

### THE IHI PRODUCTION SYSTEM

The IHI shipyard production system is a composite of facilities, personnel and material which achieves, through the careful integration of these elements, an extremely high rate of productivity. The composite system relies heavily on the thorough planning and scheduling accomplished prior to the start of steel fabrication and which is continually refined throughout a production run of ships.

The IHI production system has been perfected over a number of years to a point where an established routine of design-planning-production-control is now in effect for the manufacture of any type of ship. This routine varies only slightly from yard to yard and the basic principles of this methodology are almost never modified.

As in most shipyards the major production activities are divided into hull construction and outfitting. Each of these activities is organized and executed by a separate "!Workshop". Hull construction encompasses all steel fabrication, sub-assembly, assembly and erection of the final hull units. Outfitting is planned and organized to correspond with the hull construction work so that appropriate outfitting of components and sub-assemblies is accomplished at the best time during manufacture of the steel unit assemblies.

The manufacture of steel parts and pieces, the assembly of these components into progressively larger and more complex units, and ultimately the construction of these units into the ship itself, is the function of the Hull Construction Workshop. In IHI the process of hull construction utilizes designated material flow routes called "process lanes" for the processing of all material. "Process Lanes" extend through several different physical areas either within shops or assembly areas in a series of operations referred to as "Sub-stages". These "Sub-stages" are part of a larger process step called a "stage". Figure 2-l illustrates this organization of production into the various process lanes, sub-stages and stages.

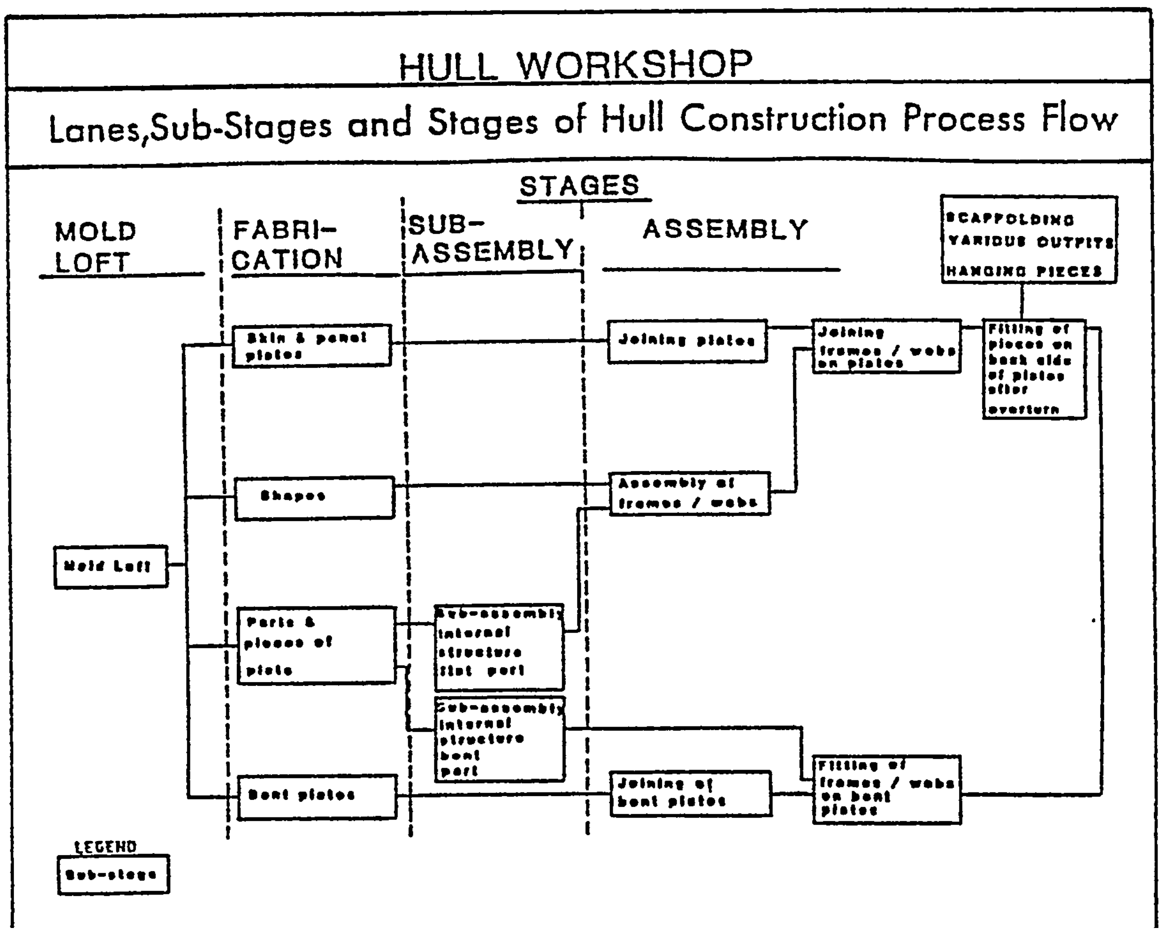



**FIGURE 2-l**

**ORGANIZATION FOR PRODUCTION**

This type of production system aligns the physical areas of the overall facility into several material flow paths which begin with the fabrication of detail parts and pieces, the subsequent sub-assembly of these pieces into one or several minor assemblies which will then be integrated into a unit. For example, in the fabrication shops the steel plates are sized, marked, cut and bent in different process lanes according to their eventual usage in flat panel or curved units. These piece parts are routed to appropriate sub-assembly or assembly areas for use in the construction of the two different types of units. The typical flow is thus from the fabrication of panels or cut pieces to sub-assembly to assembly of either flat-panel or curved units. The completed units will subsequently be moved to a unit buffer.storage area or to the platen area adjacent to the building basin. Approximately 30 to 60 percent of all ship units will be completed prior to the start of ship erection.

The second major activity of the production system is outfitting. IHI has developed its planning and production system so that as much outfitting as possible can be achieved during the build-up of the steel unit assemblies. This "pre-outfitting" has provided the IHI yards with substantial improvements in productivity over the past decade.

Essentially, outfitting is considered in three distinct stages: on-unit, on-block and on-board. On-unit outfitting is the sub-assembly of outfitting components (such as piping) into a composite for eventual installation as a sub-assembly onto a steel structure. On-block (unit) outfitting is that performed while the assembly of the steel components is being accomplished in an assembly area. At the appropriate time in the build-up of a steel assembly, outfitting will be accomplished to The maximum extent possible. on-board outfitting is that required after erection of the individual units in the builaing basin. Figure 2-2 illustrates the flow of outfitting activities during these proauc tion.stages.

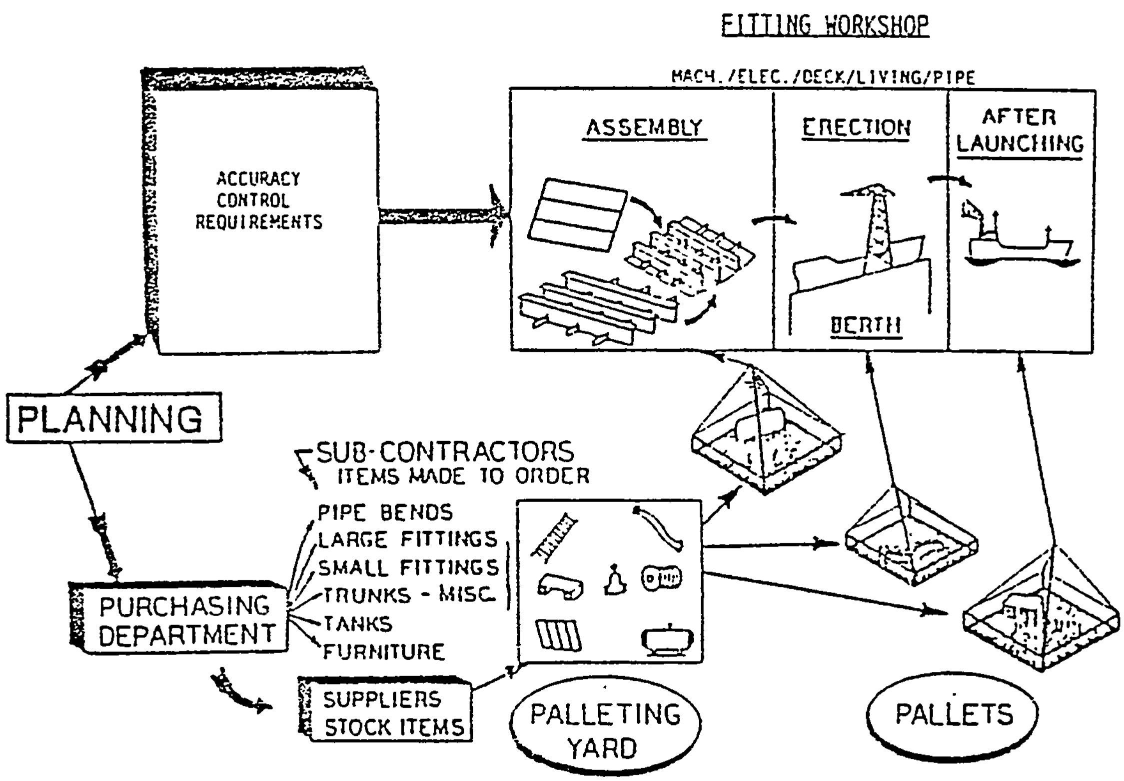



FIGURE 2-2

FLOW OF OUTFITTING ACTIVITIES

Throughout the ship construction process "mass production" techniques are utilized to obtain maximum production rates. All work is divided into discrete stages and precise processes within each stage; particular facilities are allocated to the performance of a particular operation; personnel are allocated to a single location and type of operation; and work is moved to the workers in each location. The objective throughout the production of one or several ships is to maintain the maximum flow of material through the production process in the minimum period of time. This provides a full and constant workload at each work station throughout ship construction.

Another basic objective of the system is to minimize the time consuming, expensive and relatively dangerous work during the erection stage. Therefore, accuracy of each component, sub-assembly and unit is stressed at each stage of production, and as much outfitting as possible is accomplished on the units prior to the start of erection to minimize on-board outfitting in the erected ship.

This highly effective system relies heavily on the thorough planning accomplished prior to the start of fabrication. This planning enables the total utilization of the facilities and personnel in a comprehensive and controlled manner throughout the ship construction process.

HULL CONSTRUCTION PLANNING

Hull construction planning follows a prescribed methodology which progressively breaks down and details successively lower levels of the hull until the parts and pieces at the lowest level of fabrication are completely defined. Essentially, the steps followed by shipyard engineers performing this breakdown are:

1. Unit division (i.e. dividing the ship into major units capable of being assembled, transported and erected);

2. Assembly breakdown (i.e. defining the component sub-assemblies and detail parts which constitute each of the units);

3. Specifying the fabrication, sub-assembly and assembly methods to be used in the fabrication of the detail parts and the build-up of these parts into progressively larger and more complex assemblies.

This methodology is well known to U.S. industries. It is the system developed long ago for engineering drawing development and for assembly line production. This system was developed and established as the traditional production methodology for the U.S. aircraft industry during World War II. Its application to shipbuilding is also well known and understood although few shipyards employ it to the degree that the IHI yards do.

While this breakdown of the overall product and of the successive lower level "interim" products is being accomplished, a host of other planning activities are taking place. Facilities arrangements are confirmed; fabrication, sub-assembly assembly and erection processes are determined; material requisitions are determined and issued; and manpower and performance measurement requirements are established. Figure 2-3 depicts the flow of planning activities prior to the start of hull construction.

## Preliminary Planning

Hull construction planning begins immediately upon completion of the Basic Design (accomplished by the Design Department in the Head Office of IHI in Tokyo). The Basic Design consists of: Unfaired

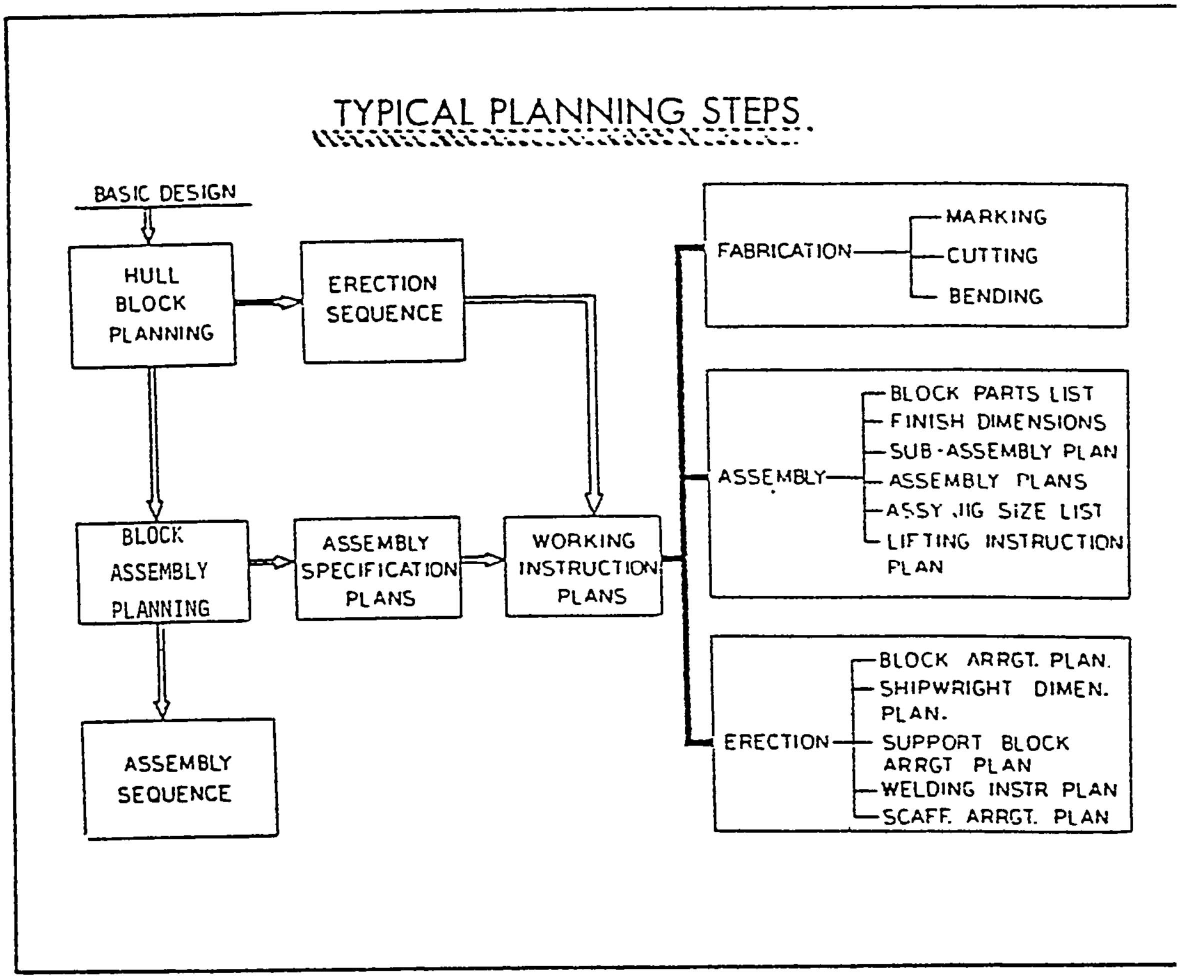
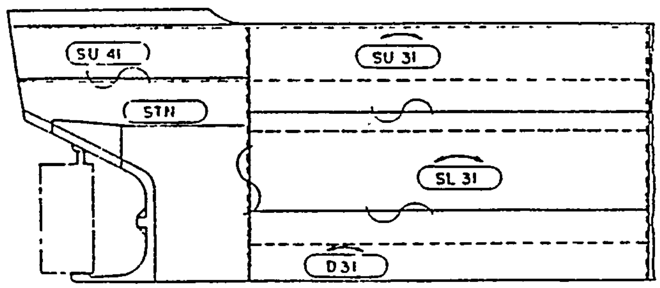


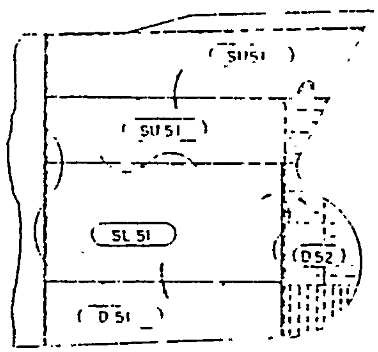

FIGURE 2-3

Ship's Lines, Midship Section, Construction Profile, General Arrangement and Machinery Arrangement drawings. On the basis of these plans, the shipyard Design Department undertakes the breakdown of the ship into "Blocks" or units. This activity is called "Hull Block Planning" and consists of dividing the ship into manageable units suitable for assembly and erection. (See Figure 2-4)

# HULL BLOCK PLANNING




BLOCKING PLAN OF AFT SECTION




BLOCKING PLAN OF FORE SECTION

FIGURE 2-4

Unit Assembly Planning

After division of the ship into manageable units, typical common-shaped units are analytically disassembled in a progressive breakdown from the entire unit to the component sub-assemblies and then to the parts and pieces which constitute the sub-assemblies. All unique units are broken down in this manner. Figure 2-5 shows a typical example of such a breakdown.

These breakdowns serve several purposes in addition to showing the basic assembly sequence of each unit. A preliminary evaluation of the assembly sequence yields details concerned with the necessary

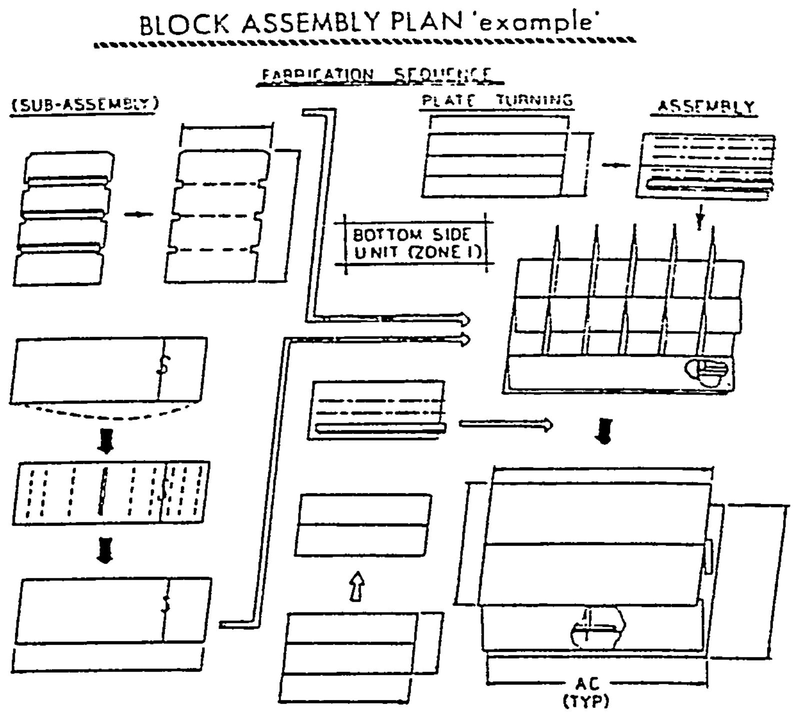



FIGURE 2-5

facilities and processes required for the assembly, e.g., required fitting jigs, probable welding processes, required assembly area size and capacity. Further details are developed including: the classification of sub-assemblies and assemblies; reference level and line; length and types of welding joints; welding edge-preparation requirements; and requirements for added material for adjusting seam and butt lines.

All of this planning is considered "preliminary" information for the development of "detailed process planning" which is documented and disseminated as "Assembly Specification Plans" and "Working Instruction Plans".

## Detailed Planning

During the preliminary planning stage, the Basic Design generated by the Head Office Design Department is refined and elaborated to the extent necessary to fix the Hull Blocking Plan. This design is referred to as the Functional Design and upon approval of the Hull Blocking Plan the Working Design is started.

At the start of the detailed planning stage, the Assembly Master Schedule is prepared from the Erection Master Schedule. On the basis of this schedule, the Material Requisition Schedule and Material Requisition Orders are prepared. Detailed Hull Construction Working Plans are also prepared by the Design Department defining the assembly units identified in the Hull Blocking Plan.

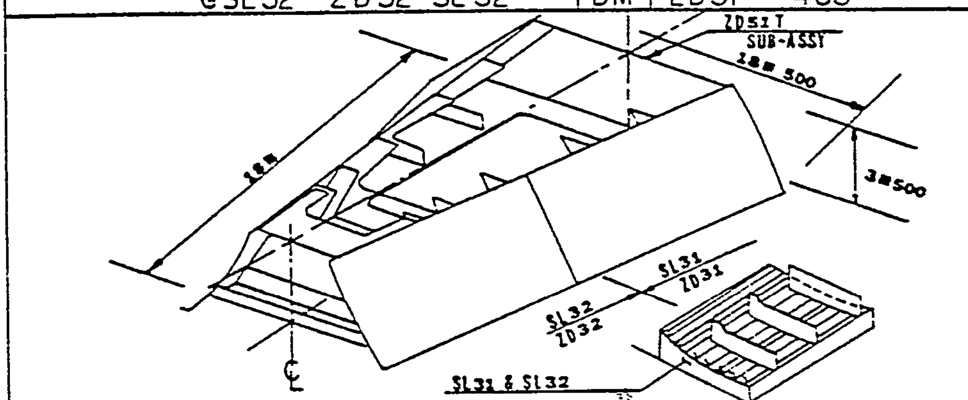
Based on these working plans and on the material requisition schedule and a Fabrication Lane Plan (which details the processing of plate steel through the fabrication shops), a Rough Cutting Plan is generated. This plan is made to assist in the preparation of Material Requisition Orders for steel plates to minimize the number of sizes, thickness and the total quantity of plates required. The purpose of the plan is to improve the usage and control of remnants and scraps; -to determine the quantity of steel required each month; and to provide guidance for the preparation of the Cutting Plan for the workshop. The Material Requisition Orders are prepared on the basis of the information in this plan.

## Assembly Specification Plans

Based on the information developed during the "preliminary process planning", formal Assembly Specification Plans are developed. These plans detail the methods to be followed during fabrication, assembly and erection. This planning is accomplished by engineering personnel in the Design Department and by accuracy control engineers in the various workshops.

## Detailed Assy. Specification Plan

| | | |
|---|---|---|
| Block | GSL31 ZD31-SL31<br>GSL32 ZD32-SL32 | WT TOTAL 58 TONS<br>DM ZD31 --- 403 |



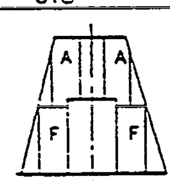
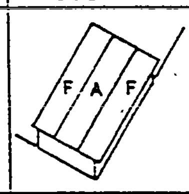
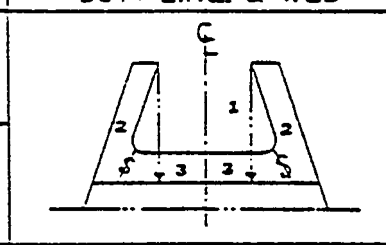

| Steps | Assembly Process | | ACCURACY CHECK Points |
|---|---|---|---|
| JIG SETTING | ZD31&ZD32 HORIZONTAL JIG | SL31 & SL32 FIXED POINT JIG | HORIZONTALLY |
| PLATE JOINING (ALL FAB. WELDING) |  |  | ASSY. REFERENCE LINE<br>BEAM-- ℄ TRANS.-FLAT<br>LONG GIR ZD32 BUTT<br>ZD32 LENGTH BETWEEN BUTT LINE & WEB |
| MARKING | ZD31 P/S<br>ZD32 FINISH<br>DIMEN. PLAN | SD31 & 32<br>BATTEN |  |
| ASSEMBLY | ZD31-32 P/S EACH<br>SL31-32 ASSY EACH SIDE PRE-ERECTION<br>PRE-ERECTION FLAT BASE ZD31<br>FITTING PARTS ON FLAT BASE | | |
| CONTROL INDEX | WL-AUTO 901M 288M | | NONE |
| MAN-HOUR | ZD31-32 250 HRS. SL31-32 420 HRS. | GS31-32 250 HRS. | NONE |

FIGURE 2-6

## Work Instruction Plans

Working Instruction Plans represent the final planning step, and are derived from the functional and detailed design,Assembly Specification Plans, and the other data which have been progressively developed from the Basic Design for each unit. Working Instruction Plans provide detail working-level data for the fabrication, assembly and erection of each unit. These plans complete the development of data from the design level information to the working level details necessary for workshop execution.

Three Working Instruction Plans are prepared for each unit in the area of fabrication: Marking Plan, Cutting Plan and Bending Plan (often the Marking and Cutting Plans will be combined into a single plan).

In the area of assembly, six plans are prepared on each unit as follows:

- Unit Parts' Lists
- Finishing Dimensions Plan
- Sub-assembly Plans
- Assembly Plans
- Assembly Jig Size Lists
- Lifting Instructions Plan

Working Instruction Plans originated for erection include:

- Unit Arrangements Plan
- Shipwright Dimensions Plan
- Support Block Arrangements Plan
- welding Instruction Plan
- Scaffolding Arrangements Plan

These plans provide all necessary information at each production stage for the proper manufacture and handling of each unit. The basic objectives intended for these plans are: I) to effect control of the total workload and the products as the work progresses through the various process lanes, sub-stages and stages of the production system; 2) to effect control of the great number of parts and pieces of material as they flow through the production processes; and 3) to provide explicit instructions to all levels of personnel concerned with the fabrication, assembly and erection of ship components.

## OUTFIT PLANNING

In IHI outfit planning begins immediately upon receipt of the Basic Design and parallels hull construction planning in the development of the Hull Blocking Plan, Unit Assembly Plans and the functional and detailed design.

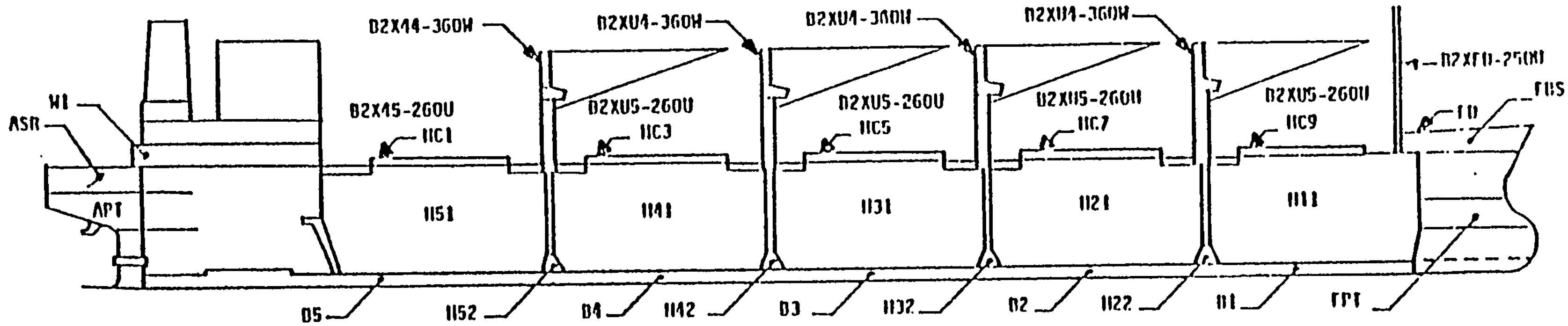
The IHI shipyards accomplish as much "pre-outfitting" of hull units as possible during the construction of these ship elements. This, of course, greatly reduces the amount of outfitting work that must be done during erection and after launch. The manhour and cost savings attributable to this approach are considerable and this approach is another factor in the high productivity achieved by these yards.

Pre-outfitting is a logical and highly effective method for reducing ship construction costs especially in light of the "modular" hull construction method used by IHI. The building of assembly units and the joining of units to form "grand units" provides an ideal condition for the installation of outfitting components and sub-assemblies at the various production stages of hull steel construction.

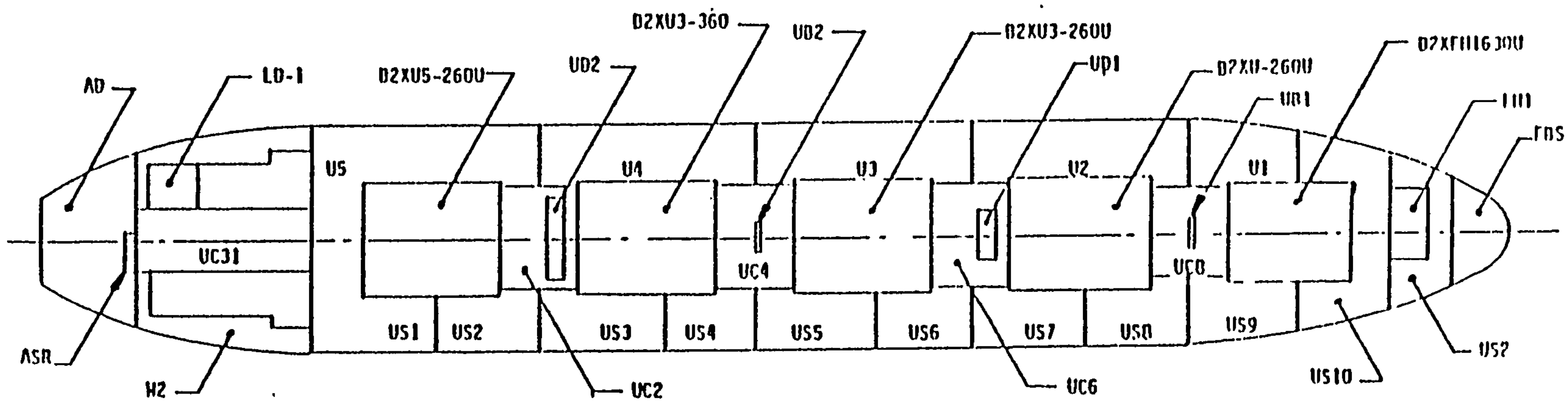
Naturally, the outfitting work performed during the build-up of hull units in the assembly areas is far less costly, less dangerous and is more accessible and amenable to down-hand welding processes. This type of outfitting also contributes to the IHI objective of shortening the work time in the building basin.

During the Detail Design stage, the data from the functional design is converted into working drawings of unit assemblies, sub-assemblies, detail parts and pieces, etc. Also, at the detail design stage an Outfitting Zone Plan is developed for the ship. This outfitting zone planning essentially sub-divides the major ship zones into.smaller areas concerned with outfitting activities in the major ship sections, i.e. cargo hold, engine room, deck house, main deck, etc. An "Outfitting Zone" is simply a geographical area (3-dimensional) of the ship having no relation to a particular system. Instead all systems within a given area are encompassed by the zone boundaries. An Outfitting Zone can represent a portion of a deck, a portion of several decks, one or more compartments, parts of adjacent compartments, etc. Figure 2-7 illustrates the Outfitting Zones identified for one type of ship.

with the identification and designation of Outfitting Zones detailed material lists are formulated together with piece drawings for the manufacture of pipe pieces, piping arrangements, and outfitting pieces and sub-assemblies. Specific material lists are prepared for the manufacture of pipe (Material List for Pipe - MLP) and for other outfitting components (Material List for Components - MLC). These material lists and the associated piece drawings are eventually scheduled for production through the yard pipe or fabrication shops.




FORE SECTION




UPPER DECK

FIGURE 2-7

OUTFITTING ZONES

In addition to the above, the Detail Design effort also produces composite drawings showing the layout of all outfitting material in specific "Work Zones" (a further breakdown of the outfitting zones into small packages of outfitting work). These composite drawings show the interrelationship of the many different systems integral to the individual work zones together with details of mounting and joining.

Upon completion of the composite drawings, the final stage of design, Work Instruction Design, is initiated. This design stage produces drawings of outfitting components which are to be installed at different production stages, e.g., sub-assembly, assembly, erection, after launch. Accompanying these drawings is another material list, the Material List for Fitting (MLF) which corresponds to the work to be accomplished at the production stage shown on the Work Instruction Drawing. This package of information describes the work to be done, the production stage at which it is to be done, and the list of materials which must be accumulated and present at the work site.

The Work Instruction Drawing, the associated MLF, the procured components and the manufactured components (i.e. by the yard) comprise a.specific work package or "pallet" as it is defined by IHI. All information and all related material is collected at the proper work site, at the proper production work stage, and at the proper time interval to enable the outfitting of specific units or on-board the erected ship.

The "pallets" of information and material correspond to the "work zones" established for a given outfitting zone. These outfitting activities are rigorously scheduled to continuously parallel the hull construction sub-assembly, assembly and erection schedules.

ADDITIONAL PLANNING

The Hull Construction and Outfit planning discussed in the foregoing pages combine the aspects of design and production into a thoroughly defined set of working drawings and plans necessary for the manufacture of the hull units, the outfitting of those units and the erection and outfitting of the entire ship.

Throughout the above planning, a.staff of Accuracy Control Engineers assists the planners and designers and formulates discrete accuracy control requirements for each unit, sub-assembly and piece part. These engineers develop detailed data concerning the vital dimensions and points of measurement to ensure that all manufactured components of the ship meet the highest accuracy standards possible. Additionally, these engineers develop a plan or scheme for providing added material at each stage of production to ensure that errors can be corrected without rework of the part and to provide for neat cutting at the various subassembly, assembly or erection stages. Accuracy Control Engineers also define the base lines which must be used for unit alignment to keep maximum accuracy throughout the production, assembly and erection processes. The selection and application of process standards to the fabrication processes is also the responsibility of these engineers.

The objective of this accuracy planning is to effect the highest production efficiency by ensuring that each of the fabricated and ,assembled components meets prescribed standards and thereby requires no re-work as the material flows through the production process. This achievement of high accuracy reduces the amount of work required at the erection stage and ensures that the completed ship will meet or exceed all quality standards and will be in true alignment as required by design specifications.

Other plans are prepared by workshop staff personnel to detail the methods for facilitating work during the erection stage and during on-board outfitting. This planning is called "Field Planning" and consists of the following types of plans.

Plan for temporary holes (in the hull during erection)

Plan for ventilation and cooling of the hull on the ways

Plan for supply of electrical power and gas lines

Plan for stools arrangement on the ways

Plan for equipment access on-board and on working staging

Plan for standard shipwrighting techniques

Plan for maintaining shaft alignment considering the initial hogging of the aft and forward ship sections

Plan for tank arrangement and testing

Plan for final dimension check items

Plan for disposal of temporary pieces for construction

## THE IHI SCHEDULING SYSTEM

The IHI scheduling system is a delineated hierarchy of schedules descending from the customer delivery requirement to the lowest working levels. The methods used by IHI in this scheduling system are not unique; however, some of the techniques are somewhat different in comparison to U.S. practice.

Basically, the system begins with the delivery schedule established by the Head Office. This schedule is reviewed in some detail by the

Production Control staff of the shipyard selected to build the ship and can be adjusted if found to be impracticable. If the yard can accommodate the ship in the time established by the Head Office, the Production Control group (in the shipyard's General Superintendent's office) formulates a Ship Construction Master Schedule which places the total building period into context with all other construction work in the yard. Placement of a new ship program into the Ship Construction Master Schedule is based on availability of facilities and personnel to accomplish the work in the desired time frame.

The Ship Construction Master Schedule becomes the guiding master schedule for the development of all lower schedules and is regarded as the one absolute and inflexible schedule thorughout the building process.

Figure 2-8 presents the hierarchy of schedules which are developed from this primary master schedule. The next schedule prepared is the Major Milestone Schedule which defines the time period designated in the Ship Construction Master Schedule for construction of a particular ship or ships in terms of key events such as planning, fabrication start, keel laying, launch and delivery. Other key events that normally constrain the ship construction process, such as delivery of main engines or other long lead-time items that are procured from outside sources, may also be included. This schedule provides information for the construction of the Erection Master Schedule.

The Erection Master Schedule prescribes the sequence to be followed in the build-up of the ship in the building basin. The several major zones of the ship (i.e., mid-body, bow, stern and house) are separately scheduled and each of the units comprising these zones are scheduled

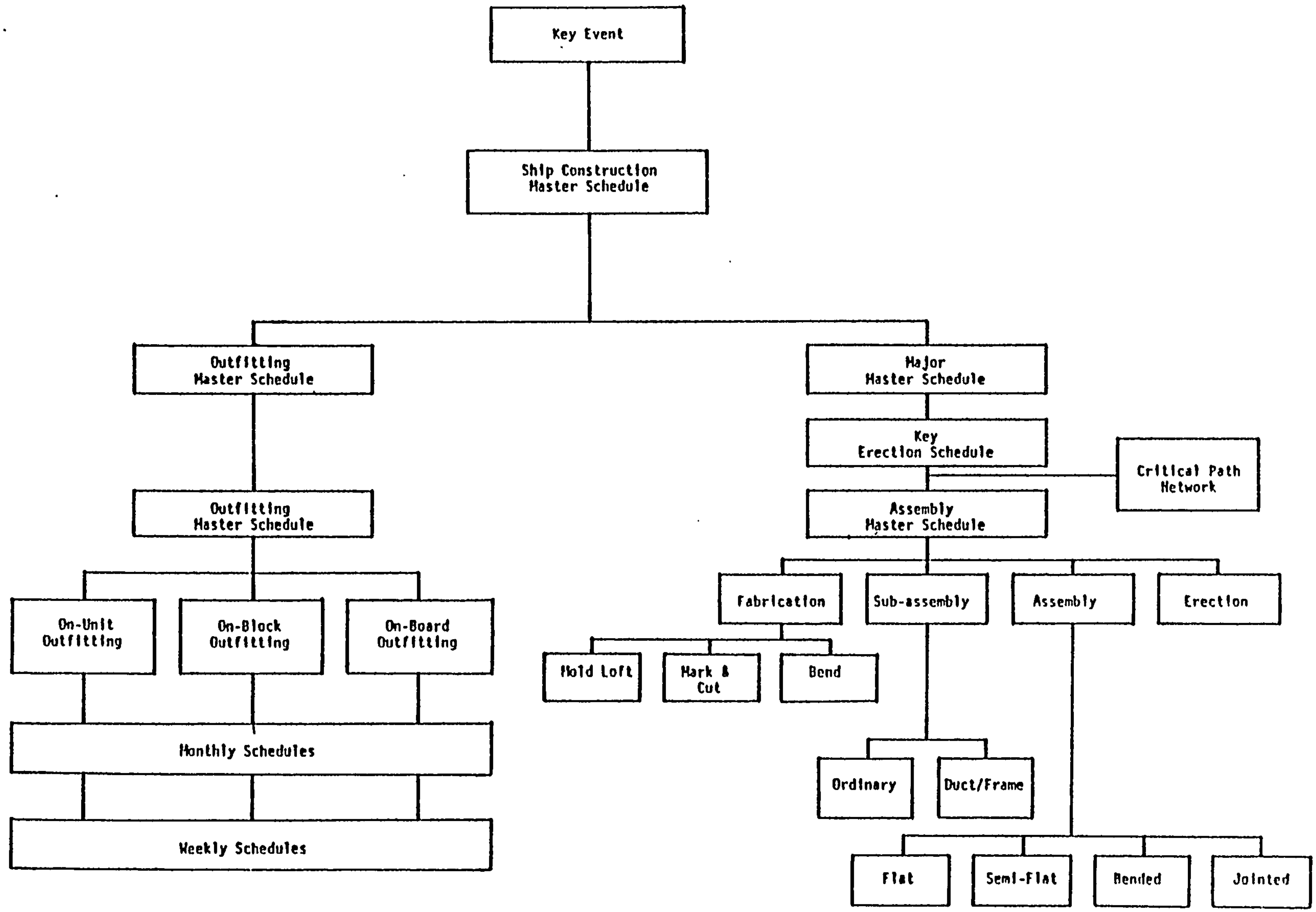



FIGURE 2-8

HIERARCHY OF SCHEDULES

individually for the precise time of landing in the basin. This erection schedule allows for the completion of all on-board outfitting work subsequent to the landing of the final unit on the erected ship. A precise set of standards is used to calculate the landing and joining of each unit to adjacent units allready in the basin. These time standards dictate the amount of time required between each unit, and the schedule is developed as a series of "set backs" from the final unit in each zone.

Based on the mandatory erection time requirements for each unit, the Assembly Master Schedule is prepared. This Master Schedule establishes the periods for assembly of each unit sufficiently ahead of the erection schedule to permit unit outfitting and transportation to buffer storage or to the building basin platen areas.

From the Assembly Master Schedule detailed subordinate schedules: for hull fabrication, sub-assembly, assembly and erection are prepared. These schedules are developed by the Production Planning and Engineering groups of the Hull Construction Workshop in conjunction with the applicable Section Managers and Foremen in the respective production stages and areas.

In the fabrication area specific sub-schedules are developed for the activities of the mold loft and for marking, cutting and bending of all materials for each of the hull units. In the sub-assembly areas, schedules are prepared for the common or ordinary sub-assemblies (such as webs) which are typical to many units and for more complex sub-assemblies containing ducting or major frame components.

Detailed assembly schedules are prepared for each hull unit.

Due to the different process lanes through which the flat versus curved units emerge, these schedules are prepared for each type of unit with somewhat different information presented thereon. Schedules are prepared for typical flat units (e.g. flat double bottom units), semi-flat units (e.g. curved shell and curved internal structure mounted on a flat panel such as the side double bottom units), bent or curved units (e.g. bow or stern units), and joined units (e.g. two units joined to allow the landing of a larger unit during erection).

The Erection sub-schedules detail the preparation, transport, buffer storage, and final erection of each unit in the building basin.

All of the above schedules are primarily concerned with the hull construction effort. In parallel with this effort, a series of outfitting schedules are prepared based on the Ship Construction Master Schedule and the hull construction schedules as they are developed for each stage of production.

After development of the Major Milestone Schedule, the Outfitting Milestone Schedule is prepared by the Production Planning and Engineering Group in the Fitting Workshop. This schedule expands the key milestones shown in the Major Milestone Schedule to include the periods where the fitting of the outfitting zones of the ship must begin and end. Other key events, which coincide with the receipt of major purchased equipment, are defined to indicate the completion of outfitting on critical sub-assemblies or units of the ship which will constrain the start of erection or the erection of specific units during the erection process.

The Outfitting Milestone Schedule provides the basis for development of the Outfitting Master Schedule. This schedule must of course coincide with the Assembly Master Schedule to allow proper time intervals for the installation Of outfitting sub-assemblies and components during the build-up of each hull unit. Unit assembly instruction plans are carefully studied to determine the time requirements for outfitting, the outfitting area, and whether it would be more efficient to install individual components or outfitting sub-assemblies (e.g. a piping sub-assembly) into the unit.

Once the Outfitting Master Schedule has been developed, the detailed subordinate schedules are prepared. Individual schedules for the build-up of sub-assemblies of outfitting components (called on-unit outfitting), for the fitting of both these sub-assemblies and individual outfitting components in the hull units, and for installation of other sub-assemblies or components on-board the erected ship are prepared for each outfitting zone. Still more detailed schedules are then constructed for each group of fitting personnel based on the fitting tasks to be accomplished in order to execute the individual sub-schedules. These work schedules cover each month of the Outfitting Master Schedule and each week of each monthly schedule. These weekly schedules prescribe the task, the personnel and the time allowed for each outfitting activity each day.

In this descending hierarchy of schedules both the hull construction and the outfitting tasks are developed and sequenced to coincide with one another and with each higher level schedule. The Ship Construction Master Schedule usually contains only two weeks slack time which can be used to accommodate any unanticipated delays. This obviously requires careful and comprehensive schedule planning at each level of schedule development and a total commitment by all personnel to meet schedule dates once they are developed. The use of overtime is permitted in order to maintain schedule position but unless overtime is purposely included in the schedules (by top-management decision) the use of overtime is restricted to the most dire circumstances.

## MANPOWER PLANNING

Manpower planning in IHI is a precise method of applying personnel resources to each task of the well defined production process. The planning accomplished for hull construction and outfitting and the exact scheduling of these activities provides the framework for the application of manpower in discrete stages, sub-stages and time periods.

The entire production process is organized around the "process lanes" system. As previously discussed, this system allocates specific types of work to particular work stations established in a fixed location within one of several process lanes. In Hull Construction these work stations are related to lofting, marking, cutting, bending, subassembly, assembly and erection. The activities of each of these work stations is defined in great detail in the plans prepared prior to the start of fabrication, and further delineated in the detailed schedules discussed in the previous section. The organization of the basic production system and this highly refined planning and scheduling allows the application of personnel to small increments of work at fixed times throughout the hull production process.

In outfitting the same basic methodology is applied although the locations and mix of personnel vary according to the type of outfitting being accomplished. Also, the fabrication of pipe is a discrete planning and scheduling effort of its own and the application of manpower is determined separately from that of hull construction and outfitting.

The computation of manpower in each of these major areas of hull construction, outfitting and pipe fabrication is based to a large extent on the historical data accumulated by the various yards from the prior construction of similar ships. This historical data has cataloged production rates per manhour in terms of weight of steel, weld metal deposited, cutting length, outfitting component weight and manhours required for sub-assembly or installation, painting and pipe fabrication. The application of these data to the same type of operations ship after ship is a routine and accurate process.

The budget planning process in IHI is not unlike that utilized in U.S. yards, although the participation of the workshops planning staffs is a unique aspect and indicates that workshop managers participate more fully in the establishment of their budgets than their U.S. counterparts.

Essentially, the overall budget is established by the IHI Head Office and refined by the shipyard General manager into working budgets for each department in each workshop. This refinement of the overall budget is accomplished both by the Production Control Department which is staff to the General Manager, and by the Production workshops. The estimate generated by Production Control is in more general terms and is based primarily on historical data collected from previous ship construction programs. Production department estimates are in precise terms of numbers of welding and fitting manhours required per day/week/month.

Subsequent to the initial estimation of manhours by Production

Control and the production shops, a Budget Meeting is held and a decision as to the operating budget is made by the General Manager. This operating budget is then issued by Production Control to the various cost centers in the yard. No adjustment of the budget is made until one or two months before ship delivery. This adjustment is made on the basis of accumulated manhour expenditures at another meeting of Production Control, the affected shop(s), and the General Manager. Figure 2-9 shows this budgeting process.

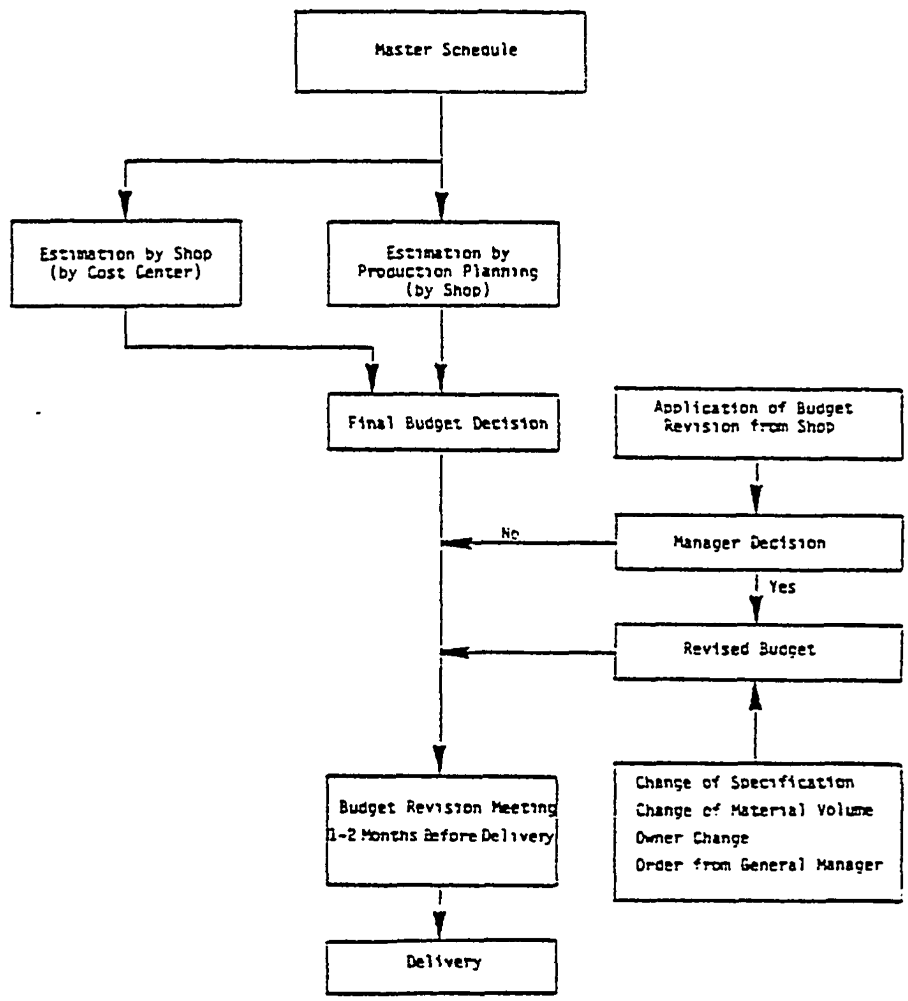



FIGURE 2-9 BUDGET PROCESS

The entire manpower planning cycle extends from the overall planning accomplished to establish the shipyard and department budgets to the manhour plans of the individual foremen of each production area. Manpower planning at the working levels consists of the identification anti scheduling of the work groups allocated either to the hull construction work stations or to the fitting tasks in the outfitting schedule. Manhours are continually weighed against the actual manhours used on previous ships and by the various factors of manhours/ton, manhours per length of weld deposited, cut lengths, outfittings weight, cable lengths, etc. This manpower planning, when combined with the production planning and scheduling forms a complete framework of data for the performance of all work in each area of production.

PRODUCTION CONTROL

Production Control in the IHI yards happens as a natural consequence of the production planning and scheduling system. The organization of the hull construction and outfitting shops and activities, the detailed planning accomplished for each of these activities and the use of working level schedules for small groups of personnel allows close monitoring and control of each step of the production process.

Basically, three organizations are concerned with production control: the Production Control Department and the Production Planning and Engineering groups for the Hull Construction Workshop and the Fitting Workshop respectively. This de-centralized control parallels the de-centralization which characterizes the planning and scheduling activities. The Production Control Department is primarily concerned with the overall yard aspects while the Production Planning and Engineering groups are concerned with the detail control of the workshop activities.

The activities of these three groups start from the overall yard planning and scheduling and descend to the levels of the individual work stations. However, once production has begun the daily inputs from the working levels are coalesced into the control information required to judge the status of the total program. In the planning phase the production control system works from the top down, in the production phase the system works from the bottom up.

Production Control Department

The Production Control Department is responsible to the shipyard General Manager for the planning and scheduling of yard facilities and manpower for all ships and other types of construction in process and backlogged. This department prepares the Ship Construction Master Schedule; accomplishes the planning of production functions in terms of weight, cutting length, welding length, outfitting weight, cable length, etc.; prepares the overall yard manpower plans; prepares the overall yard work load schedule; and prepares the manhour efficiency control curves used to monitor shipyard performance.

This top-level planning and control is translated to Successively lower levels of the organization until each organization (i.e., workshop, section, group) and each production stage (i.e., fabrication, assembly, erection and outfitting) is fully detailed by planning, schedules and performance control data.

Because of the thoroughness of the planning and scheduling, usually only minor changes to the top-level plans and schedules are required. If changes are required, they are generally accomplished at the working levels such that the top-level plans are not affected. Although the overall status of each program is closely monitored by the Production Control Department, the majority of the actual production control activity is performed by the workshop Production Planning and Engineering groups.

Production Planning and Engineering Groups

These groups, called the workshop staff groups, attend to a multitude of planning,. scheduling, coordination and control functions. As previously mentioned, these groups are responsible for working with design engineers in formulating the various plans and schedules to be used throughout the production process. They also interface closely with the foremen, Section Managers and the Production Control Department in the preparation and updating of man-loading and performance control charts and graphs.

Once the top-level shipyard planning is accomplished by the Production Control Department, the workshop staff groups begin the development of the detailed plans and schedules for the actual operations of the various hull and outfitting groups. The wealth of planning data developed during the detail design process together with the master schedules form the basis for the preparation of these detailed shop and group plans and schedules.

Production Control of the various activities occurring in the Hull Construction Workshop involves the planning and scheduling and subsequent monitoring and control of the manpower, processes and methods utilized in these activities. The hull construction process, for purposes of production control, is divided into the following areas: total hull, lofting, fabrication, sub-assembly, assembly and erection. Within each of these areas several different means are established to monitor production performance. Table T2-1 shows the various control graphs prepared for each area.

TABLE T2-1

HULL CONSTRUCTION CONTROL GRAPHS

| AREA | TYPE OF GRAPH | BASE |
|---|---|---|
| TOTAL HULL | Advance Curve - Wgt. | Day |
| | M/H | Erected Wgt. |
| | M/H | DM |
| LOFTING | Engr. Dwgs. Vs. Loft Dwgs. | Day |
| | M/H Vs. Plan | Day |
| FABRICATION | Steel Wgt. Vs. Plan | Day |
| | M/H per Steel Wgt. | Day |
| SUB-ASSEMBLY | M/H | Wgt. |
| | M/H | DM |
| ASSEMBLY (Ea. Area) | M/H Vs. Wgt. | Day |
| | M/H Vs. DM | Day |
| ASSEMBLY (Total) | M/H | Wgt. |
| | M/H | DM |
| ASSEMBLY WELDER | M/H | DM |
| ASSEMBLY FITTER | M/H | DM |
| ERECTION | Advance Curve - M/H | Day |
| | Erected Wgt. | Day |
| | M/H | Wgt. |
| | M/H | Bn·L |
| | Hull Fitter M/H | Bn·L |
| | Welder M/H | Bn·L |

Legend:
DM - Deposit Meter
M/H - Manhour
Wgt. - Weight (ton of steel)
Bn·L - Weld length x difficulty coefficient

As mentioned previously, Outfitting activities parallel the hull construction activities of sub-assembly, assembly and erection. Witn the exception of pipe fabrication and painting, these activities involve several or all of the fitting groups in the outfitting organization.

Although the outfitting organization is structured essentially around the outfitting zones of the ship (i.e. Interior or Accommodations Fitting group, Deck Fitting, No. 1 and No. 2 Machinery Fitting, and Electric Fitting group) the manloading and scheduling of the outfitting tasks is oriented toward On-unit (i.e. sub-assembly of outfitting components), On-block and On-board activities. Hence, the outfitting tasks require a blending of the skills of each of the organizational groups into the type of work groups required for a given task. Also, since the outfitting tasks are not of a repetitive nature (such as those in hull construction) and since these tasks are performed in a number of different locations, a distinctly different type of manhour and schedule control is required.

In outfitting there is far more reliance on the use of the monthly and weekly schedules than on performance control charts or graphs although such control graphs are used to measure the progress of each group.

As discussed above, Production Control evolves from the top-level planning, scheduling and control graphs to the successively lower levels of production. In outfitting this top-level planning and control is manifested by the Shipbuilding Master Schedule, the Outfitting Milestone Schedule, the Outfitting Master Schedule and the corresponding shipyard and Outfitting Section control charts. Beneath this level production control charts are prepared to reflect progress of each work group during On-unit, On-block and On-board outfitting. Figure 2-10 illustrates this descending hierarchy of controls and the correlation between these control charts and the related schedules.

## LEVINGSTON APPLICATION OF IHI TECHNOLOGY

During the course of the Technology Transfer Program, Levingston has adopted many of the IHI techniques of production planning and control. This has entailed a detailed study of the IHI system and a careful evaluation of the parts of the system applicable to LSCo.

As a result of the LSCo. studies, the decision was made to convert the Levingston production system to an approximation of the IHI system over a period of time and to initiate changes to the Levingston scheduling system which would lead eventually to an IHI-type,system. All of the planning data originated for the first of the modified Future 32 bulk carriers being built by Levingston was converted piece-by-piece to the IHI methods.

In early 1980 Levingston began to modify its production system to one using the concept of the "Process Lanes" system of IHI. To avoid confusion during this period of re-organization the term "Gate System" was adopted to describe the production system of LSCo. Essentially, the system comprises a series of "gates" which are equivalent to the IHI sub-stages and stages (i.e., plate cleaning, marking, cutting, bending, sub-assembly, assembly, erection and the several outfitting stages of sub-assembly of outfitting components, installation on assembly units, and installation on-board the erected ship). Each of

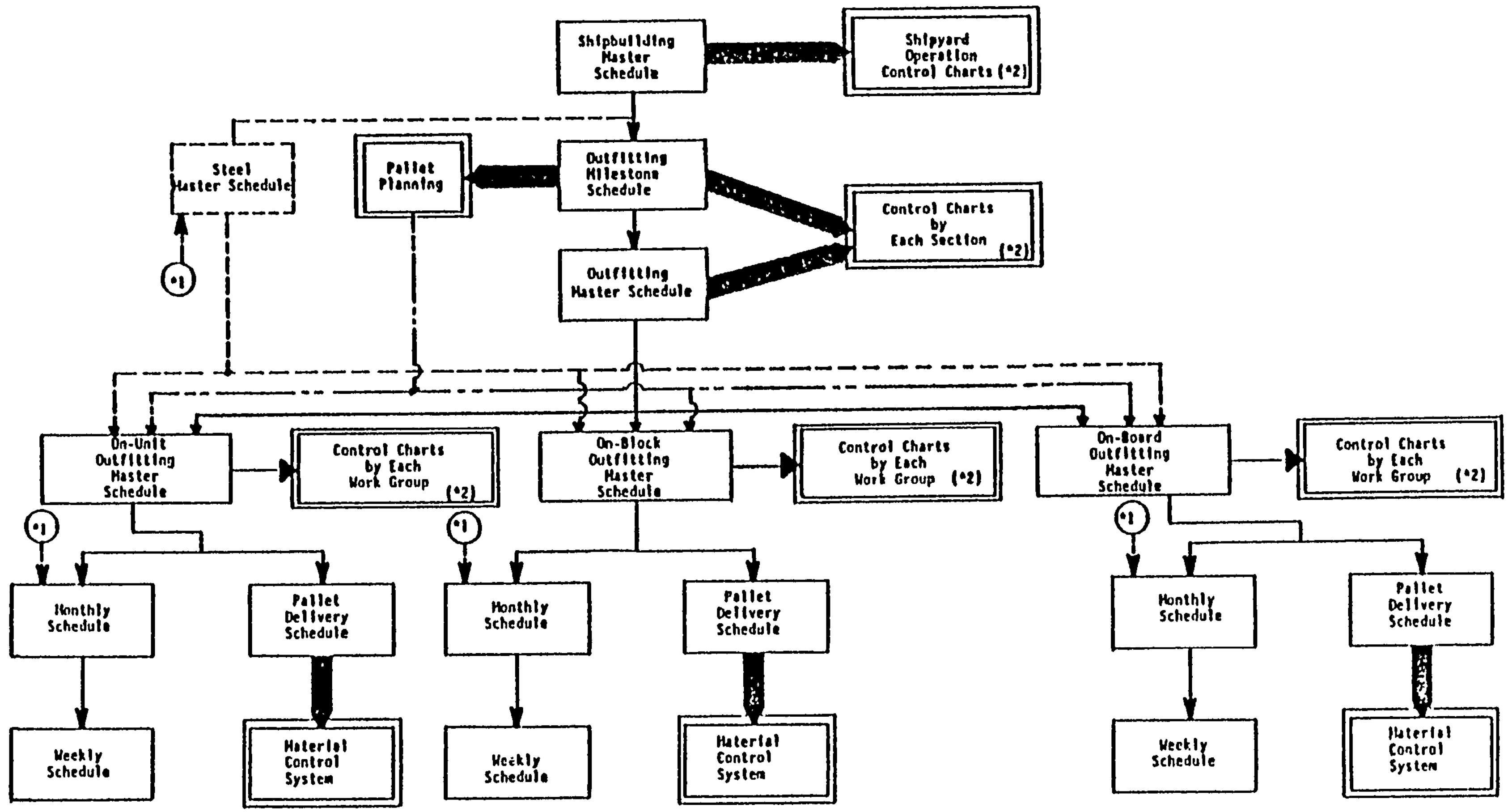



FIGURE 2-10

OUTFITTING SCHEDULING SYSTEM (IHI)

these gates has an assistant foreman or foreman permanently assigned and a number of worker personnel. The gates process steel according to detail gate schedules to support the assembly, outfitTing and erection master schedules.

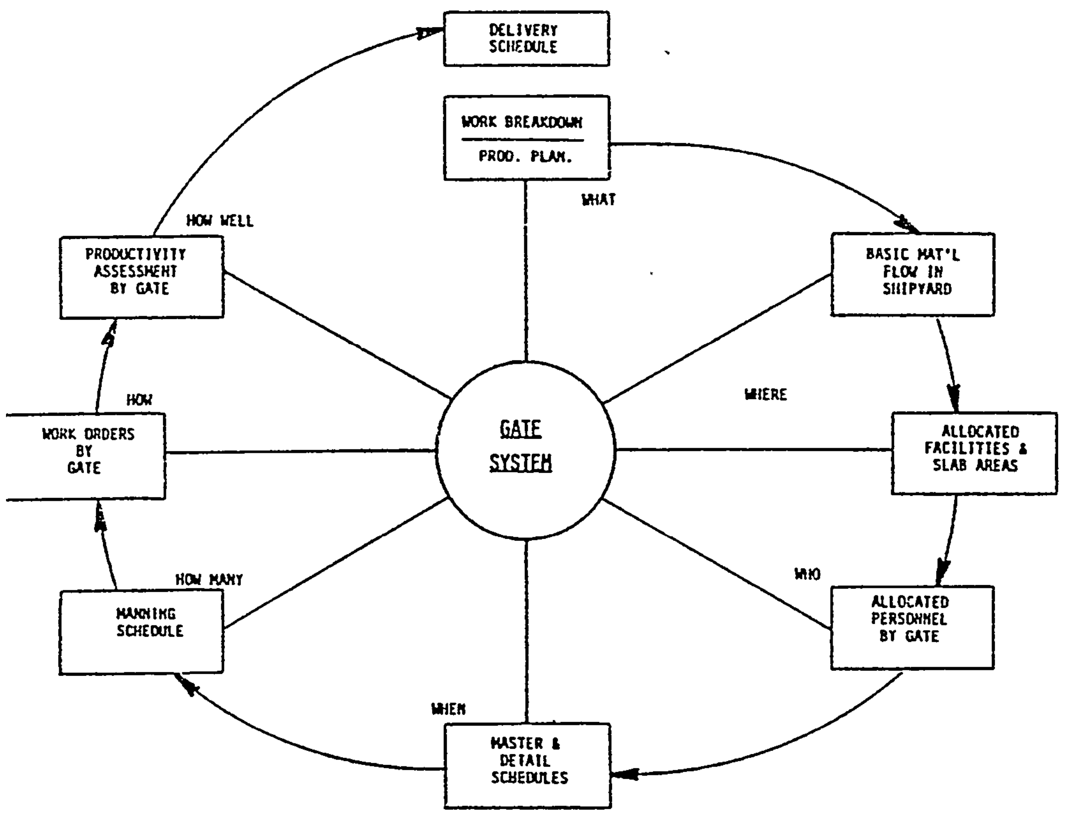



FIGURE 2-11

GATE SYSTEM

With the adaptation of the "Gate System" Levingston is fully committed to the application of the IHI production planning and control techniques. These techniques have necessarily been modified to fit the facilities, capabilities and personnel organization of Levingston. many of the peripheral aspects of the system, such as Accuracy Control, decentralized planning and production control, the decentralized organization of work groups and staff groups, and total communication of planning and scheduling information to the work positions, have not yet been addressed in their fullest degree for application.

Figure 2-12 presents a diagram of the current Levingston planning, scheduling and manning control system currently in operation.

## APPLICATION TO U.S. SHIPBUILDING

The application of the IHI Planning and Production Control system to typical U.S. shipyards is entirely practicable and desirable. The institution of this system, however, requires major modification not only to the planning and scheduling practices of the typical U.S. yard but also to the production system itself.

As explained previously, the heart of the Japanese system is the organization of the production flow through 'Process Lanes". These lanes are the essential ingredient to the establishment of the planning and production control methods utilized by IHI. This may entail some radical changes in yards which have not been structured around an "interim product" or "module" type of ship construction.

The institution of the IHI system requires a thoroughly developed plan which must be executed at the beginning of each new contract. Since the majority of planning for production needs to be accomplished prior to the start of fabrication, this planning should be incorporated

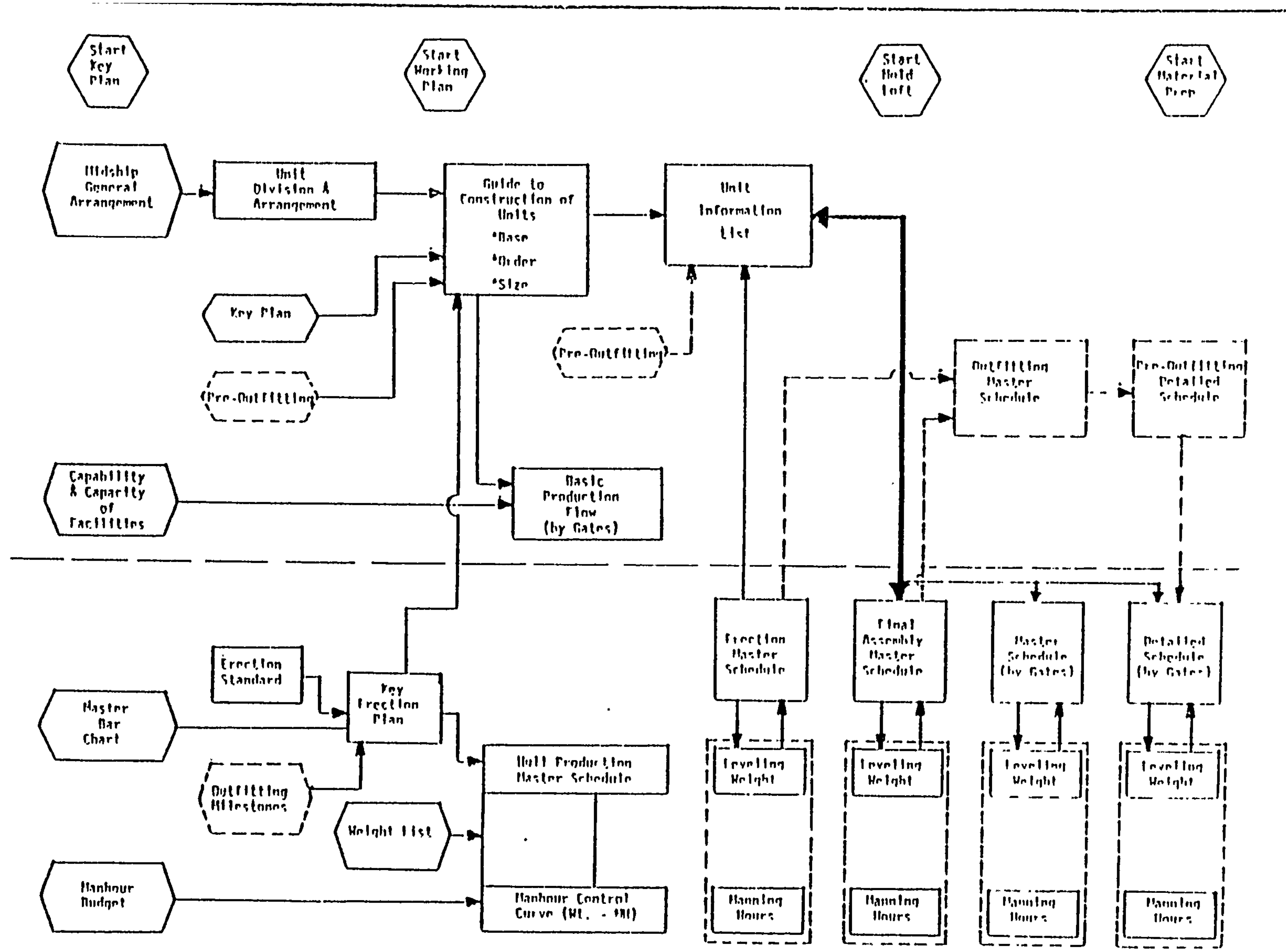



FIGURE 2-12

LSCO. PLANNING & SCHEDULING FLOW

into the design effort and, in fact. be a part of the design development. Naturally, in order for this planning to be meaningful, the production system, both hull construction and outfitting, must be thoroughly developed and in place to support a rapid and optimized production schedule once fabrication has begun.

Several major obstacles present themselves in the institution of this type of planning and control system. The most formidable, of course, is the realignment of the production system into a "Process Lanes" type of organization. The second is the development of the planning and production control system organized around the new production structure. Additionally, re-training of personnel, material flow/handling/control, pre-outfitting, and the application of accuracy control and quality control methods to the new system must all be investigated to ensure that all aspects are integrated to form a precise composite that does indeed benefit and not degrade production rates.

Levingston's study of the IHI system has derived one over-riding axiom for the application-of IHI practices, that is: the IHI ship construction system is a well developed and highly integrated whole, pieces of which can be adopted for use in U.S. yards and can be effective, but only through the adoption of the total system can any great increase in productivity be effected. This applies especially to the planning and production control system. Only through the adoption of the IHI production system does the direct application of the IHI planning and control system have meaning and, similarly, only through the adoption of the production system does the IHI pre-outfitting methodology have significant benefit. Each piece of the planning and production system is dependent upon every other piece. One piece cannot stand alone.

Currently, Levingston has implemented only a portion of the planning methodology used by IHI. Table T2-2 shows the planning techniques presently utilized by LSCo. versus those of IHI. The planning shown in the table that has not been adopted by LSCo. is of course, accomplished in one form or another, but is generally less formal and less discretely identified than that of IHI.

TABLE T2-2

PLANNING AND CONTROL TECHNIQUES ADOPTED BY LEVINGSTON

| IHI Planning & Control Technique | Adopted by LSCo. |
|---|---|
| Hull Block Planning | Yes |
| Block Assembly Planning | Yes |
| Assembly Specification Plans | Not Completely |
| Work Instruction Plans | No |
| Marking Plan | |
| Cutting Plan | |
| Bending Plan | |
| Block Parts Lists | |
| Finishing Dimensions Plan | |
| Sub-assembly Plans | |
| Assembly Plans | |
| Assembly Jig Size Lists | |
| Lifting Instructions Plan | |
| Block Arrangements Plan | |
| Shipwright Dimensions Plan | |
| Support Block Arrangements Plan | |
| Welding Instruction Plan | |
| Scaffolding Arrangements Plan | |
| Outfit Planning | |
| Zone Planning | Yes |
| Material Ordering Zones | No |
| Work Zones | Yes |
| MLS - MLP - MLC - MLF | Mat'l Information List |

The IHI Planning and Production Control System is a comprehensive and effective system in the IHI shipyards, but because of its total orientation toward the production system, methods, processes and techniques of the IHI yards, its application to U.S. yards is dependent on the willingness of U.S. yards to change their production methodology. There is little doubt that should a U.S. yard successfully replicate the IHI planning and production system that such a system would have a significant effect on productivity although, because of the cultural differences between the two countries, U.S. yards may never achieve the productivity levels experienced by Japan. Many more aspects of productivity, besides those of planning and the production system, will influence the ultimate productivity equation and, although this area of production is by far the most significant in terms of technology that can be adopted by the U.S., it is entirely possible that the areas of non-technological application (such as personnel relations) can produce an influence of equal proportion. In any case, U.S. yards cannot help but derive benefit from the study of this technological area.

# SECTION 3

# FACILITIES & INDUSTRIAL ENGINEERING

## SECTION 3

## FACILITIES CAPABILITIES AND CAPACITY

A study was conducted in early 1979 to document Levingston facilities, capacities and throughput rates and to establish a baseline for future comparison.

IHI examined Levingston's facilities and made a number of proposals for improvements. After empirical analysis of these recommendations, the ones compatible with Levingston's growth objectives and budget constraints were selected for further analysis.

Following the analysis of Levingston's facilities and alternative facility changes is an IHI facility analysis which documents facilities at the IHI-Aioi shipyard in detail. A comparison analysis of IHI's and Levingston's facilities illustrates differences between the shipyards.

### LSCo FACILITY STUDY

Levingston's facilities were documented in the Facility Capacity and Capability Study completed July 31, 1979 which documents LSCo's facilities as they existed at the beginning of the Technology Transfer Program. The report measured throughout rates for the various facilities on the basis of production of a dry bulk carrier.

In general, the condition of the Levingston shipyard prior to implementation of the Technology Transfer Program can be characterized as follows:

1) The Facility Capability and Capacity Study summarized throughput rates for each area studied, as given below:

| FACILITY | THROUGHPUT RATE |
|---|---|
| Outfitting: | |
| Pipe Shop | 1.28 ships/year |
| Steel Areas: | |
| Shop 5 (N/C Machine) | 1.40 ships/year |
| Transportation Equipment | 1.80 ships/year |
| Assembly Areas: Fitters (Dept. 4) | 1.79 ships/year |
| Assembly Areas: Welders (Dept. 6) | 2.03 ships/year |
| Assembly Areas: Shop 5 (Dept. 5) | 2.11 ships/year |
| Shop 6 (Current Panel Shop) | *1.98 ships/year |
| Shot Blast and Faint | 2.00 ships/year |
| Sandblast and Faint | 2.72 ships/year |
| Steel Storage | 4.20 ships/year |

*Current panel shop capacity was based only on construction of midship panel sections (Zone 1) due to efficiency, space and equipment limitations. Therefore, this figure actually represented midship sections per year. Additional capacity would permit construction of additional zones, including the deck house panels.

The above data indicated the constraining areas to be the N/C machine in Shop 5 for steel construction and the pipe shop in outfitting.

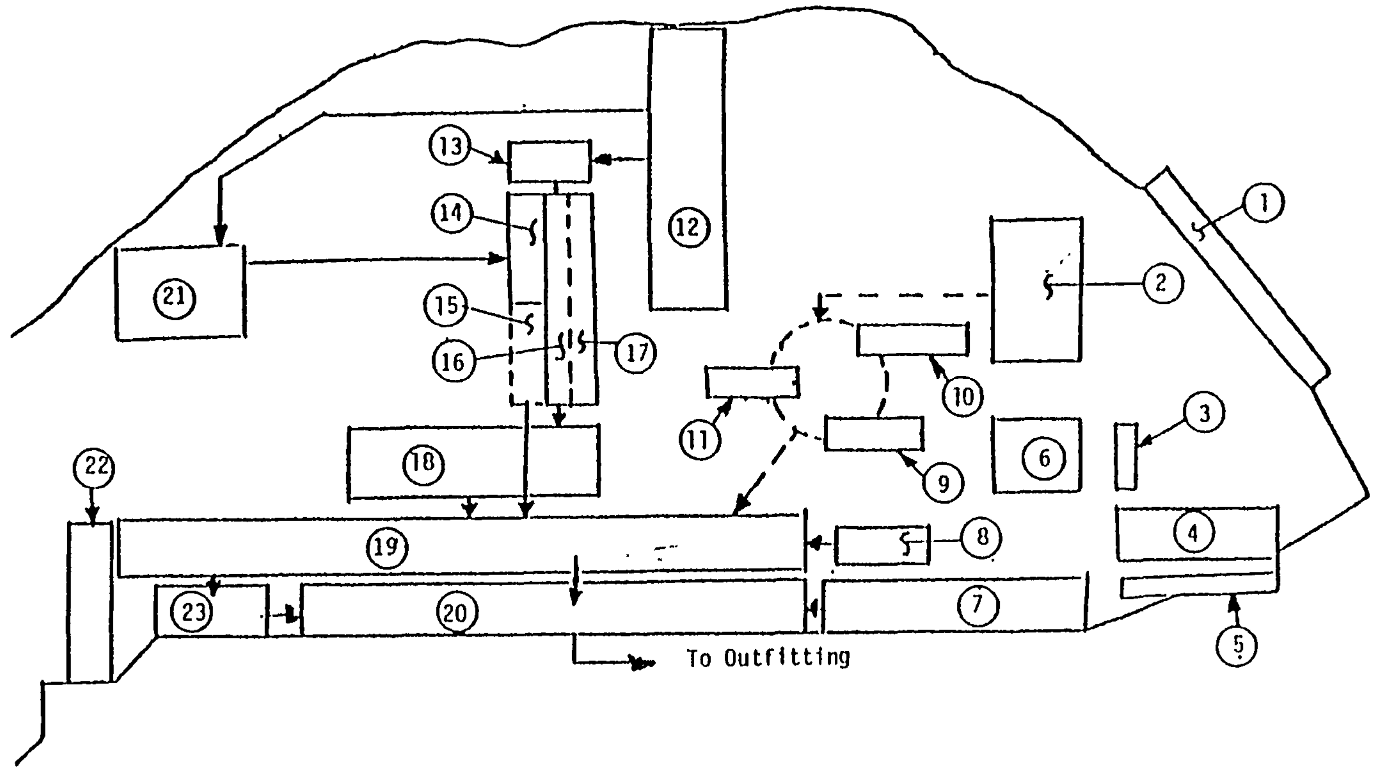
2) Units were fabricated and assembled on slab areas where space was available with no central planning of unit placement. Units were built where a location could be found. Space was not used to maximum effectiveness, nor was there an overall plan for an orderly flow of materials from fabrication to erection sites.

   Figure 3-1 the LSCo layout prior to TTP, shows a general view of the facility layout and material flow. Figure 3-2 shows how the Gate System has been applied to the existing facilities arrangement.

3) Insufficient and inadequate slab facilities were in existence.

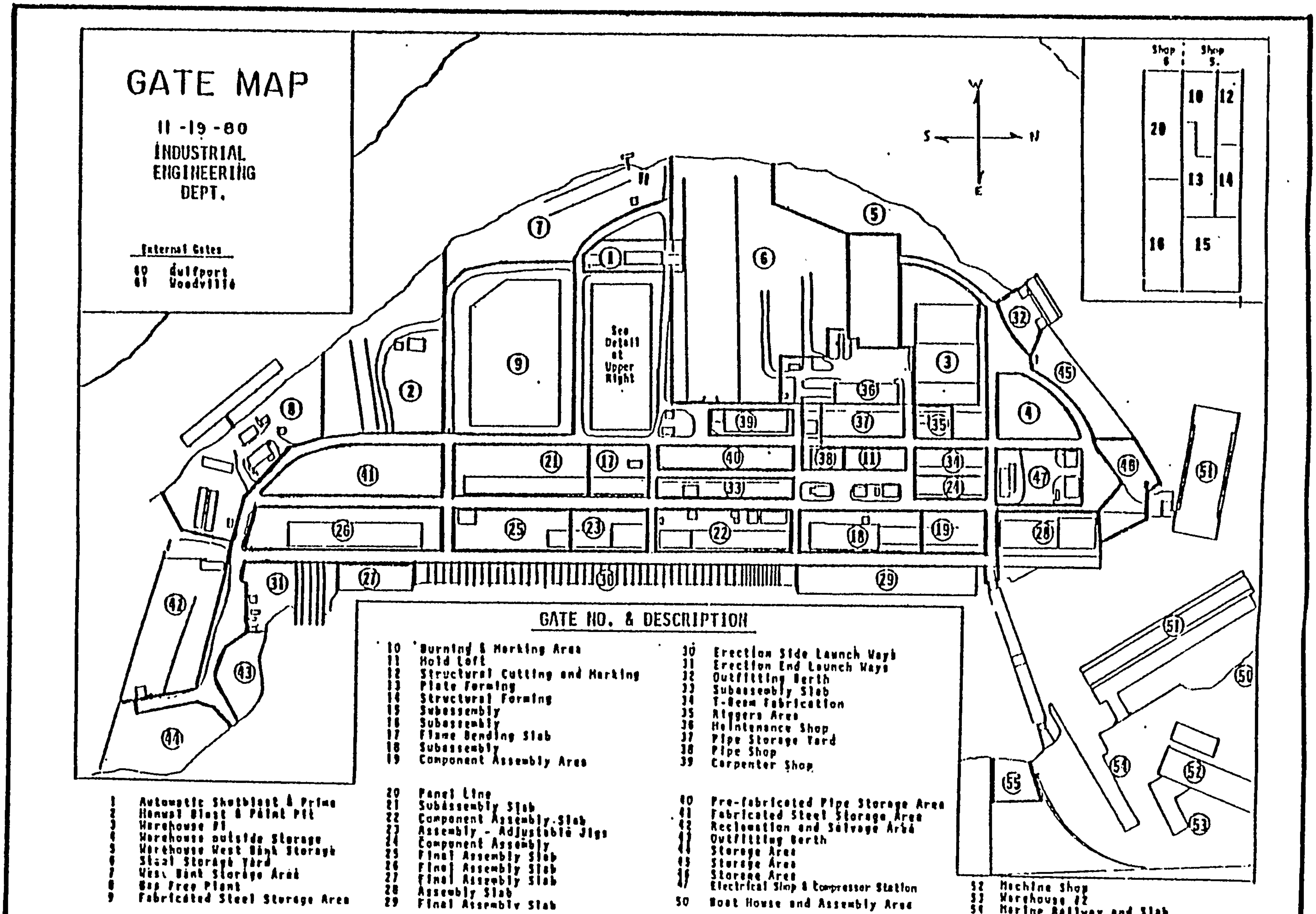
4) No covered panel line was in existence.

1. OUTFITTING
2. WHSE & REC'G
3. ELECT.
4. ASSEMBLY
5. OUTFITTING
6. SUB-ASSEMBLY
7. ASSEMBLY
8. FAB SHOP
9. PIPE SHOP
10. MAINTENANCE SHOP
11. CARPENTER SHOP
12. STORAGE
13. SHOT BLAST
14. PANEL
15. SHOP
16. PLATE FAB
17. LONG'L FAB
18. SUB-ASSEMBLY
19. SUB-ASSY & ASSEMBLY
20. ERECTION/SIDE-LAUNCH
21. SAND BLAST
22. END LAUNCH
23. ASSEMBLY




GENERAL FLOW OF MATERIALS AT LEVINGSTON

FIGURE 3-1



GATE MAP
11-19-80
INDUSTRIAL ENGINEERING DEPT.
External Gates
60 Gulfport
61 Woodville
See Detail at Upper Right
Shop 6
Shop 5
W
S
N
E
GATE NO. & DESCRIPTION
1 Automatic Shotblast & Prime
2 Manual Blast & Paint Pit
3 Warehouse #1
4 Warehouse outside Storage
5 Warehouse West Bank Storage
6 Steel Storage Yard
7 West Bank Storage Area
8 Gas Free Plant
9 Fabricated Steel Storage Area
10 Burning & Marking Area
11 Mold Loft
12 Structural Cutting and Marking
13 Plate Forming
14 Structural Forming
15 Subassembly
16 Subassembly
17 Flame Bending Slab
18 Subassembly
19 Component Assembly Area
20 Panel Line
21 Subassembly Slab
22 Component Assembly Slab
23 Assembly - Adjustable Jigs
24 Component Assembly
25 Final Assembly Slab
26 Final Assembly Slab
27 Final Assembly Slab
28 Assembly Slab
29 Final Assembly Slab
30 Erection Side Launch Ways
31 Erection End Launch Ways
32 Outfitting Berth
33 Subassembly Slab
34 T-Beam Fabrication
35 Riggers Area
36 Maintenance Shop
37 Pipe Storage Yard
38 Pipe Shop
39 Carpenter Shop
40 Pre-fabricated Pipe Storage Area
41 Fabricated Steel Storage Area
42 Reclamation and Salvage Area
43 Outfitting Berth
44 Storage Area
45 Storage Area
46 Storage Area
47 Electrical Shop & Compressor Station
50 Boat House and Assembly Area
52 Machine Shop
53 Warehouse #2
54 Marine Railway and Slab


FIGURE 3-2

5) Shop layouts were not planned in an orderly fashion and consequently not conducive to efficient material processing resulting in substantial delays for craftsmen and material handling equipment and poor utilization of area for material storage and buffer storage.

6) Outfitting work was performed almost exclusively on-board. No pre-outfitting or modular outfitting was attempted.

## IHI PRODUCTION IMPROVEMENT SUGGESTIONS

IHI proposed the following improvements in the areas listed:

Mold Loft: Purchase N/C drafting machine.

Fabrication and Sub-assembly: Line marking rather than punch marking on the N/C burning machine; Increased size and plate turning capability on presses in Shop 5; Clearly defined sub-assembly line in a specific area.

Assembly: Panel line installation; Adjustable curved unit assembly jigs; Auxiliary lifting equipment on cranes.

Erection: Crane capacity limits size of units that can be built at LSCo; Use higher ratio of automatic and semi-automatic welding methods; Moveable scaffold units are more effective than conventional scaffolding.

General: Effective utilization of various jigs at every stage.

## COMPARISON ANALYSIS

It is difficult, and not particularly meaningful, to make a simple comparison of overall facilities between the IHI and Levingston shipyards. Therefore, this report relates specific facility areas that IHI felt could most effectively benefit Levingston and other medium size U. S. shipyards in allocating available capital resources.

A major difference is that the IHI facilities are basically built into an assembly line operation in order to maximize throughput of any given machine or piece of equipment. Each operation is scheduled to deliver a specific quantity of product within a given period and depends on the preceding operation for prompt and continuous delivery. At Levingston the method of operation results from the philosophy of fabricating, assembling and erecting pieces as individually needed results in only short-term (or non-existent) facility planning, uneven work flow, inefficient use of equipment, and on-the-spot decision making.

To summarize the facilities listed in this report which underwent comparison and study, Figures 3-3 and 3-4 are provided.

## IHI FACILITY ANALYSIS AND COMPARISON

For purposes of analysis and comparison, the IHI shipyard in the city of Aioi was selected because of its similarity in size to Levingston and other medium size U. S. shipyards. The Aioi yard is very well equipped with facilities and technologies found in few U. S. yards of comparable size.

The productivity of the Aioi shipyard is consistently high. Total production is currently at 6,000 metric tons per month with a total employment of about 2,700. During the shipbuilding boom these figures peaked at 12,000 tons per month and an employee complement of 4,000. These figures do not include employment and production from the large group of subcontractors which are also heavily involved with the IHI yards.

Figure 3-5 provides an overall view of the layout and material flow in the Aioi yard.

## SUMMARY OF FACILITY COMPARISONS

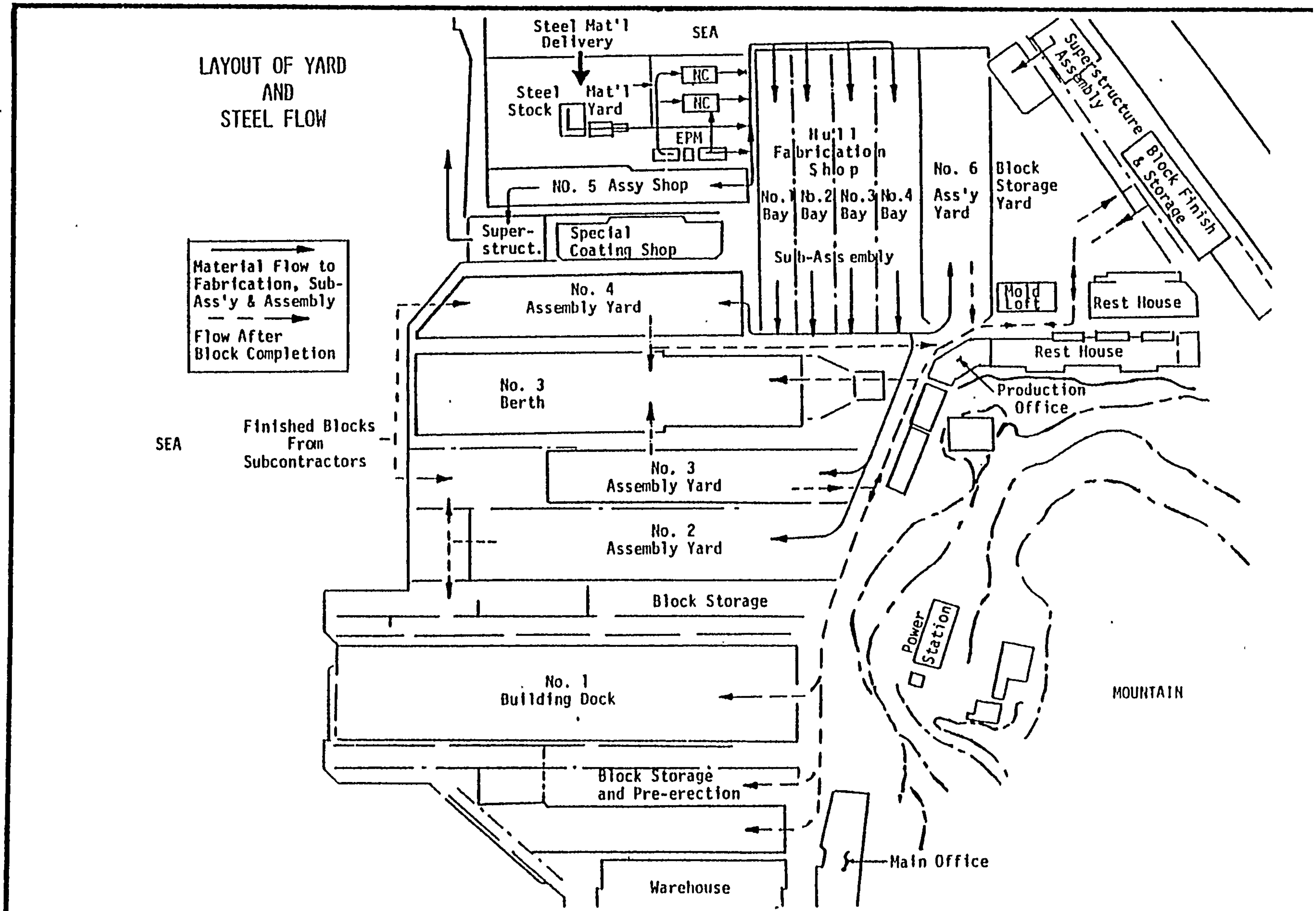
| | FACILITY | IHI -AIOI | LEVINGSTON |
|---|---|---|---|
| 1. | Mold Loft | a) 1/10 Scale Drafting machine<br>b) EPM system enlarges image to full size using precision optical projector | a) None<br>b) None |
| 2. | Fabrication & Sub-assembly | a) 3 N/C burners (AIOI)=6,000 8,000 tons/mo. Cuts plates requiring high precision and repetition Line marking system<br>b) Forms pieces by flame bending after machine bending<br>cl 2 Web assembly areas: 1) straight line 2) special webs | a) 1 N/C burner=1,500- 1,800 tons/mo. Cuts variety of plates Punch marking system<br>b) Forms by mechanical means only<br>c) No specified sub-assembly area for web frames, etc. |
| 3. | Assembly | a) 2 "flat plate" panel lines<br>b) Adjustable curved unit assembly jigs ("pin" jigs)<br>c) Assembly areas assigned for a unit according to pre-planned flow | a) Panels assembled on slabs<br>b) Permanent, fixed-type jigs<br>c) Assembly in available spaces determined by Production Superintendent |
| 4. | Erection & General | a) Portable scaffolding<br>b) Units constructed in positions allowing high utilization of auto and semi-auto welding including one-sided welding | a) Conventional scaffolding<br>b) Welding method prescribed by construction method. No one-sided welding |
| 5. | Outfitting | a) Pipe mass-produced in shop<br>b) Pipe bending utilized<br>c) High pre-outfitting, modular outfitting<br>d) Pallets used extensively to transport materials | a) Pipe fabricated at erection site<br>b) No auto bending- use fittings<br>c) No pre-outfitting<br>d) No palletization system |

FIGURE 3-3

| AREA | FACILITIES STUDY | PURPOSE OF STUDY | EXISTING CONDITION | DESIRED RESULT |
|---|---|---|---|---|
| I. Mold Loft | -N/C Drafting machine | -To determine if machine could increase loft output, decrease loft time and improve cutting accuracy. | -Every new drawing or revision to a curved section must go through a manual drafting process.<br>-Large scale templates and models are required in the mold loft. | -Decrease engineering time an estimated 15-20% of a manhours/contract.<br>-Decrease mold loft manhours, estimated at 50% of manhours/contract. |
| II. Fabrication & Sub-assembly | -N/C Cutting machine | -To improve accuracy of cutting, utilization of the N/C cutter, and to increase output. | -Inaccurate cutting, causing adjustment or repair.<br>-Too much reliance on N/C for detail parts.<br>-Cutting speed = 14 in/min. | -Better accuracy<br>-Full utilization or major cutting.<br>-Cutting speed = 85 in/min. |
| | -Optical tracing machine | -Can it increase effective use of N/C burner by cutting detail parts? | -N/C machine cuts all size parts. | -Use N/C machine for major cutting, optical tracing machine for detail parts. |
| | -Flame bending | -Determine application of flame bending to forming shapes. | -Presses & rolls used for forming. | -Use of flame bending technique in a separate area to supplement forming operation by machine. |
| III. Assembly | -Panel Line | -Determine savings with panel production in covered area, assembly line fashion. | -Panels produced on outside slab areas. | -Increased throughput by enclosing the panel operation & establishing mechanized flow process. |
| | -Assembly Jigs | -Review application of adjustable jig. | -Use of fixed jigs, useful only for one unit. | -Use an adjustable jig to have application to all variable size jigs. |
| IV. Erection & General | -Scaffolding | -Compare cost of renting, building or buying scaffolding. | -Much scaffolding is rented, remainder is built. | -Buy scaffolding if it is economical. |
| | -Welding | -Review welding equipment & welding processes for improvements. | -Only two-sided welding in affect.<br>-No thought given to build units with the intent of utilizing the most effective welding technique. | -Implement one-sided welding whenever possible.<br>-Plan construction of units with welding procedure in mind. |
| V. Outfitting | -Pipe shop | -Study improvements to be gained through larger area, improved layout and better pipe fabrication system. | -Pipe shop not designed for large scale production-pipe fabrication performed at erection site. | -Efficient pipe fabrication and handling. |
| | -Pipe bender | -Determine use of automatic pipe bender. | -Curves in pipe achieved by cutting pipe & using ells & fittings. | -Bend pipe to eliminate use of fittings & save labor. |
| | -Palletization | -Determine savings by using pallets to transport materials. | -Materials transported individually by mobile crane, or on standard size skids. | -Transport material in groups or pallets. |

SUMMARY OF LSCo FACILITY STUDIES

FIGURE 3-4




IHI AIOI SHIPYARD
FIGURE 3-5

## LSCo/IHI AIOI FACILITIES COMPARISON

A detailed comparison between IHI's Aioi shipyard and Levingston has been undertaken to show the IHI facilities at Aioi in contrast with Levingston, first near the beginning of the Technology Transfer Program in February, 1979, and again in April of 1980 at the end of the facilities study conducted under TTP Sub-task 4.1. The results of these comparisons are shown in the following data:

### IHI - LSCo FACILITY COMPARISON

(Area - $Ft^2$)

| Name | IHI | LSCo (2/79)* | LSCo (4/80) |
|---|---|---|---|
| **Steel Storage** | | | |
| Plates | 37,700 | 90,000 | 131,000 |
| Structurals | 17,500 | 55,000 | 102,000 |
| Total | 55,200 | 145,000 | 233,000 |
| Covered | -0- | -0- | -0- |
| **Fabrication Areas** | | | |
| Shotblast and paint | 9,500 | 6,400 | 6,400 |
| Marking | 17,500 | 5,200 | 8,950 |
| N/C Cutting | 29,600 | 4,400 | 7,650 |
| Manual cutting - plate | 30,400 | 6,000 | 5,250 |
| Manual cutting -structurals | 5,300 | 6,000 | 6,000 |
| Flame planer | 8,400 | 3,200 | 1,950 |
| Plate bending | 17,750 | 10,450 | 21,400 |
| Flame bending | 17,750 | 6,000 | 6,000 |
| Storage - fab. pieces | 16,900 | 4,700 | 74,250 |
| Sub-assy - flat pieces | 48,000 | 10,000 | 24,400 |
| Sub-assy - curved pieces | 30,600 | 45,200 | 49,700 |
| Total | 231,700 | 107,550 | 211,950 |
| Covered | 231,700 | 62,300 | 64,250 |
| **Assembly Areas** | | | |
| Panel line(s) | 128,400 | 33,200 | 35,600 |
| Flat panel unit (assy & stg) | 118,000 | 67,200 | 103,400 |
| Curved unit (assy & stg) | 72,800 | 14,800 | 14,800 |
| Cubic unit (assy & stg) | 65,200 | 16,600 | 16,600 |
| Superstructure (assy & stg) | 45,200 | 58,400 | 58,400 |
| Pre-erection (unit-to-unit) | 40,500 | 12,800 | 12,800 |
| Total | 470,100 | 203,000 | 241,600 |
| Covered | 318,800 | 8,200 | 15,600 |

| Name | IHI | | LSCo (2/79)* | | LSCo (4/80) |
|---|---|---|---|---|---|
| Erection (Launchways) | 188,200 | (end) | 94,000 | (side) | 94,000 |
| | 142,000 | (end) | 17,100 | (end) | 17,100 |
| **Outfitting (areas not included above)** | | | | | |
| Module assembly | 34,000 | | | | 5,000 |
| On-unit outfitting area | 111,400 | | | | |
| On-board outfitting wharf | 64,350 | | 6,000 | | 6,000 |
| Superstructure outfitting | 37,200 | | | | |
| Painting area | 23,700 | | 93,000 | | 124,200 |
| Pipe shop | 59,500 | | 8,400 | | 8,400 |
| Fabricated pipe storage | 25,500 | | 3,000 | | 24,000 |
| Misc. assembly - O/F | 28,700 | | | | |
| Deck outfitting | 2,150 | | | | |
| Accom. O/F and preparation | 1,500 | | | | |
| Machine shop | 11,000 | | 16,000 | | 16,000 |
| Propeller & shaft work area | 1,600 | | | | |
| Painting workshop | 2,650 | | | | |
| Other outfitting | 11,250 | | | | |
| Total | 414,500 | | 126,400 | | 183,600 |
| Covered | 145,700 | | 24,400 | | 24,400 |
| **Warehousing & Supplies** | | | | | |
| Stock Part warehouse | 41.000 | | 36,000 | | 36,000 |
| Small mach/accom supplies | 39,000 | | 77,000 | | 128,500 |
| Elect workshop & supplies | 9,700 | | 2,000 | | 2,000 |
| Oils and paints | 27,700 | | 1,600 | | 1,600 |
| Raw pipe, misc O/F steel | 58,100 | | 25,600 | | 37,600 |
| Scrap materials | 14,000 | | 40,000 | | 40,000 |
| Other | 24,550 | | | | 13,000 |
| Total | 214,050 | | 182,200 | | 258,700 |
| Covered | 137,850 | | 39,600 | | 50,100 |
| Total Ground Area (including Repair, etc.) | 6,832,965 | | 5,235,200 | | 5,235,200 |
| Total Utilized Area | 1,715,750 | | 875,250 | | 1,239,950 |
| Total Covered Area | 834,050 | | 134,500 | | 154,350 |

NOTES:

*Some data of individual process areas for LSCo on 2/79 are estimated where specific sites were not designated.

**LSCo outfitting areas are included as "assembly areas". IHI has some areas designated specifically for outfitting work, in addition to the fabrication and assembly areas where outfitting is also done.

IHI

Types of ships built: Bulk Carrier
Product Carrier
Tanker
Container Ship

| Building | No. 1 Building Dock | No. 3 Building berth |
|---|---|---|
| | 291.5m length<br>60m breadth<br>12m depth<br>95,000 gross tons<br>180,000 deadweight tons | 287m length<br>46m breadth<br><br>91,000 gross tons<br>164,000 deadweight tons |

| Quays: | Length | Depth |
|---|---|---|
| No. 1 | 240m | 6m |
| No. 2 | 99m | 5m |
| No. 4 | 250m | 6m |
| No. 7 | 169m | 8m |
| No. 8 | 169m | 6m |
| No. 9 | 100m | 7m |
| No. 10 | 100m | 5m |
| No. 11 | 200m | 6m |
| No. 12 | 340m | 9m |

The most significant improvements at Levingston during the Technology Transfer Program were in the following areas:

| Area | Additional Amount | Main Improvement |
|---|---|---|
| Steel Storage | 88,000 $ft^2$ | Better arrangement, especially for storage of structurals and for steel remnants. |
| Fabrication Areas | 104,400 $ft^2$ | Allocated space for flame bending process.<br><br>Added designated space for fabricated steel storage.<br><br>Improved utilization of shop space for sub-assembly. |

| Area | Additional Amount | Main Improvement |
|---|---|---|
| Assembly Areas | 38,600 $ft^2$ | Expanded steel fabrication shop to enclose panel line operations. |
| Outfitting Areas | 57,200 $ft^2$ | Added space for module assembly, fabricated pipe storage, and for painting of unit assemblies. |
| Warehousing | 76,500 $ft^2$ | Added space for storing supplies (covered building) and for raw pipe storage in racks. |

A clearly significant portion of the IHI facility is covered. This provides the obvious benefits of stabilized production due to less dependence on weather factors, and allows easier compliance with the strict national pollution standards.

A percentage comparison of covered areas by each production stage, between current IHI and LSCo facilities is as follows:

| Area | IHI | LSCo |
|---|---|---|
| 1. Steel storage | 0% | 0% |
| 2. Fabrication | 100% | 30% |
| 3. Assembly | 65% | 6% |
| 4. Launchways | 0% | 0% |
| 5. Outfitting | 35% | 13% |
| 6. Warehousing | 65% | 19% |
| Total (excluding 1 and 4) | 62% | 17% |
| Grand Total | 49% | 12% |

## PRODUCTION METHODS

The methods specifically covered in this section include: marking and cutting, panel line assembly, sand/shot blasting, zone outfitting including pre-outfitting and palletization, welding, and jigs and fixtures.

### HULL CONSTRUCTION

The methods used in hull construction cover the range of processes from the mold loft to the erection stage. Process flow charts provided by IHI to describe these processes are shown on the following pages as Figures 3-6 through 3-12.

These processes are briefly explained as follows:

#### Mold Loft

The mold loft work is classified into three categories:

1) Panel
2) Longitudinal Frame
3) Internal Member
   a) EPM Process
   b) NC Process

#### Fabrication

The fabrication process is classified into four categories:

1) Panel
2) Internal Member
3) Angle
4) Built-up Longitudinal

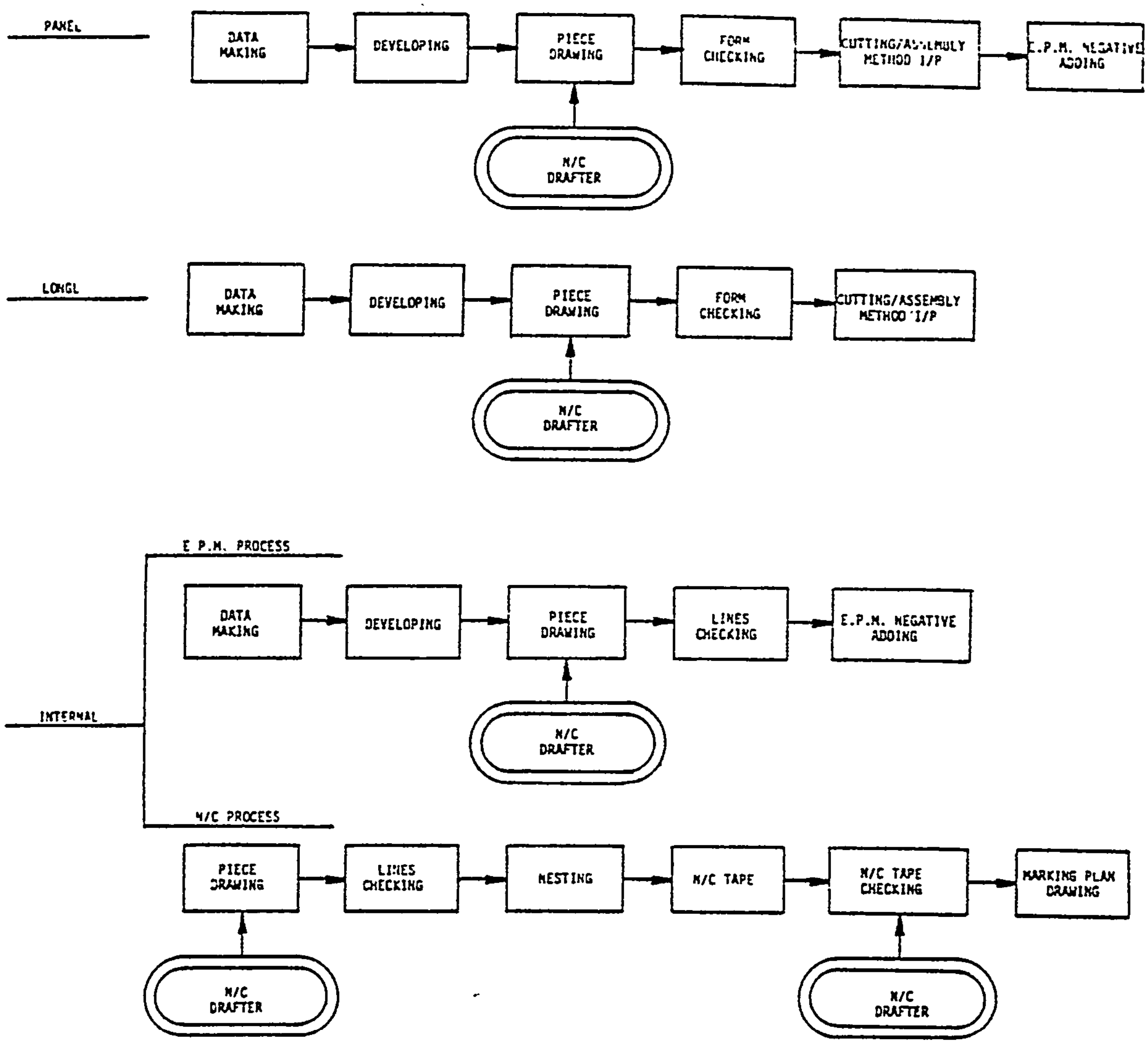
#### Sub-Assembly

Approximately one-third of the total assembly weight is produced at the sub-assembly stage in advance of the start of assembly work.

#### Assembly

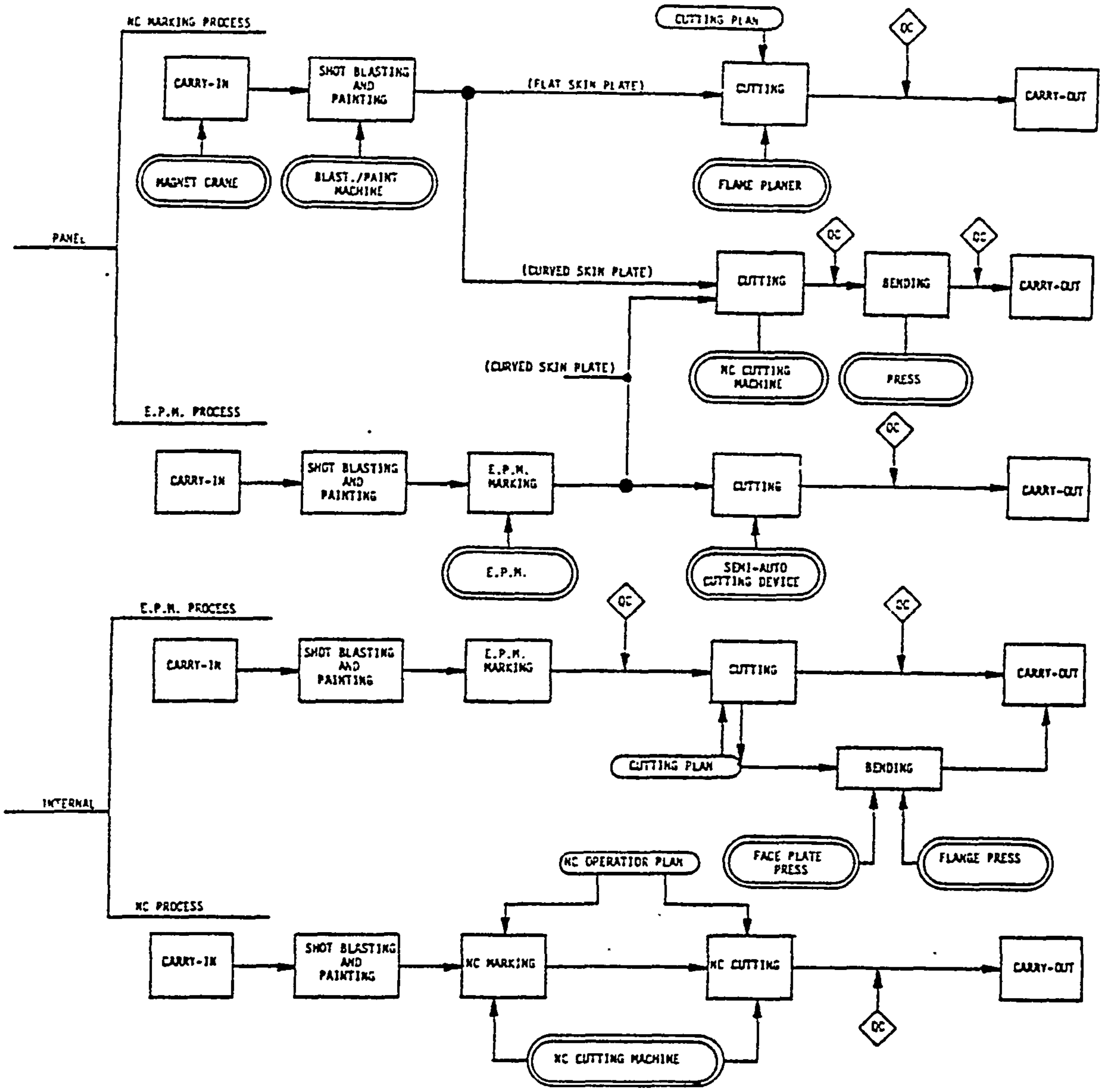
Assembly work is classified into three categories:

1) Panel Unit
2) Semi-Panel Unit
3) Curved Panel Unit




FLOW CHART OF MOLD LOFTING

FIGURE 3-6




**FLOW CHART OF FABRICATION (1/2)**

**FIGURE 3-7**

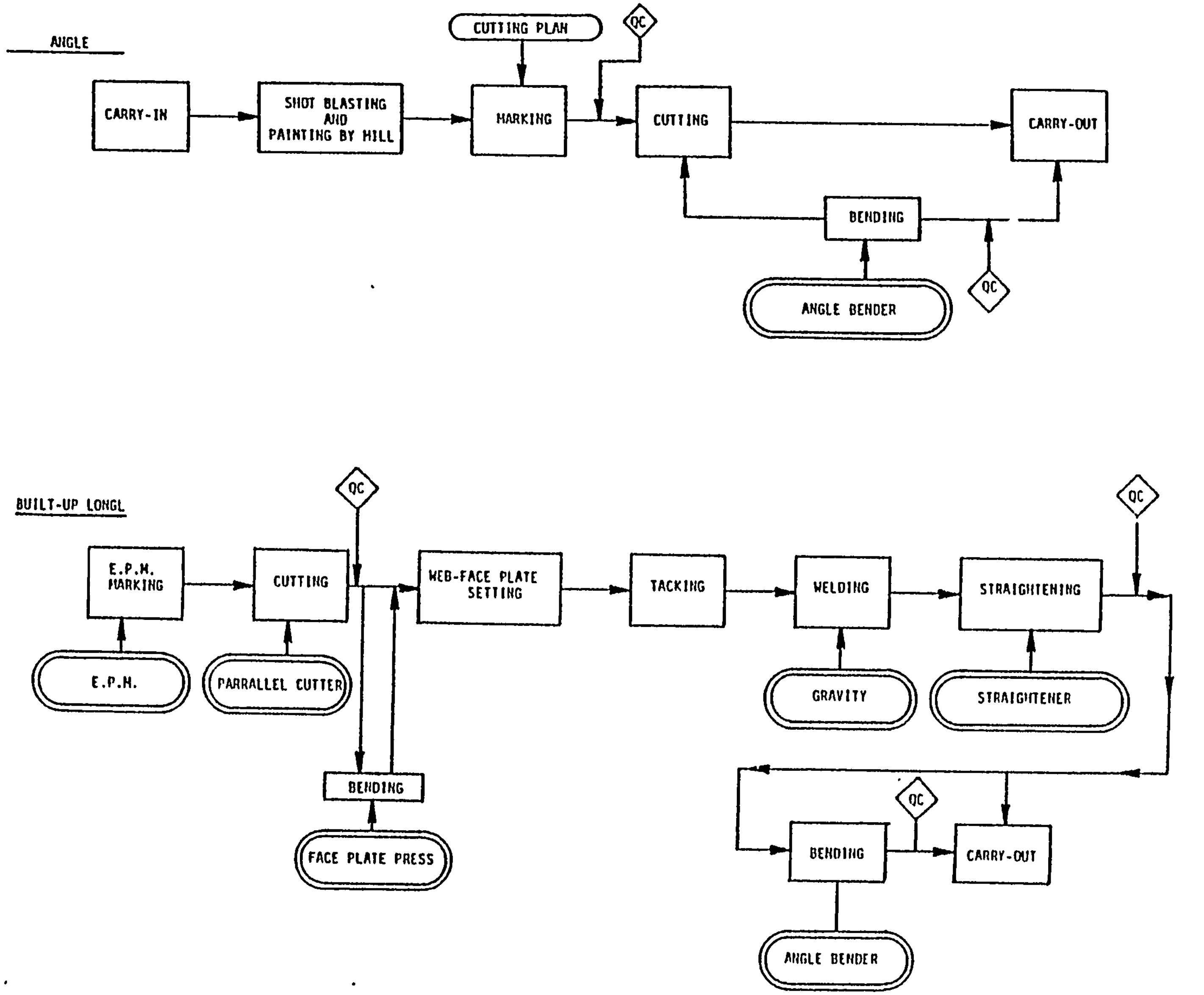
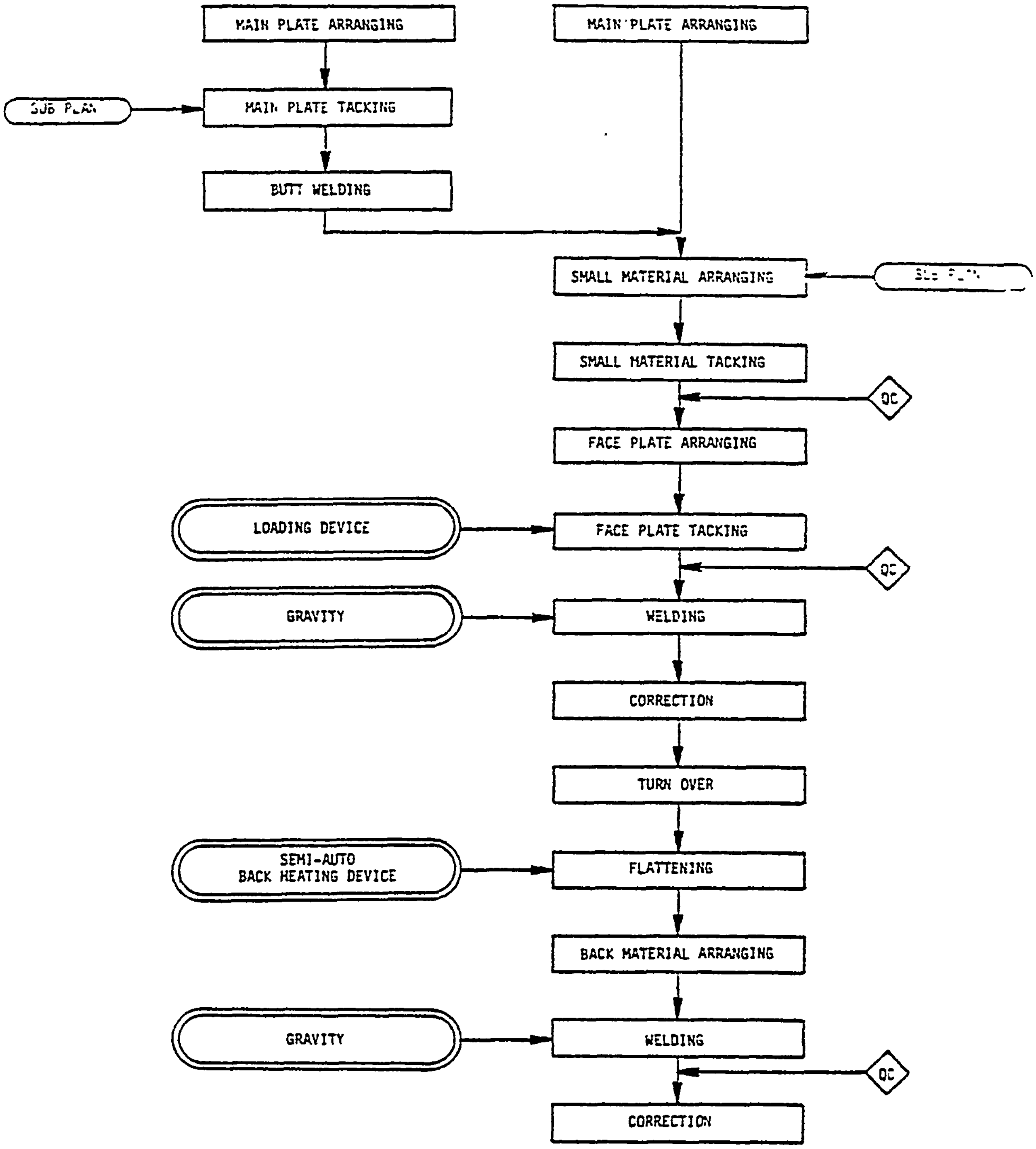
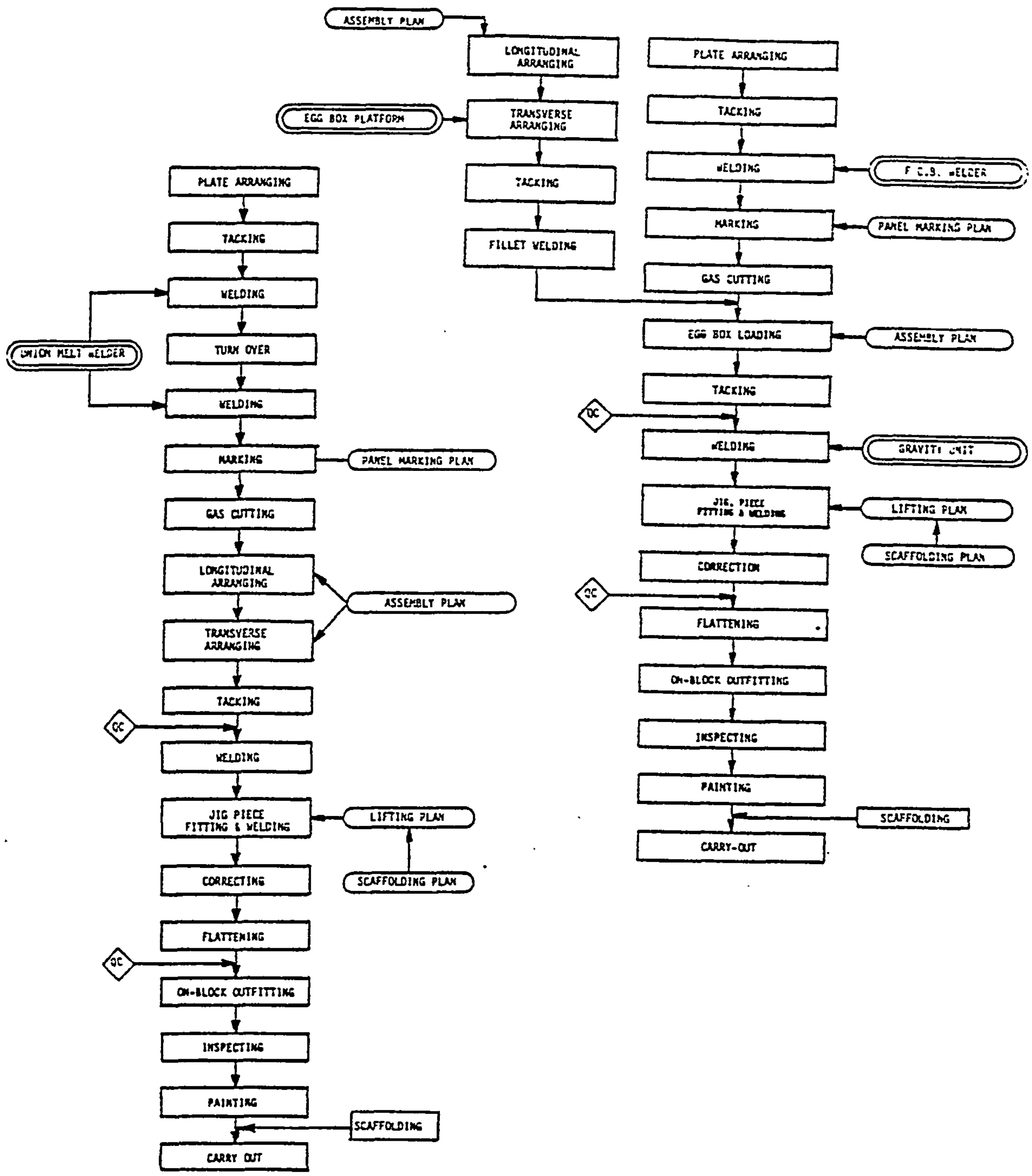



FIGURE 3-8 FLOW CHART OF FABRICATION (2/2)



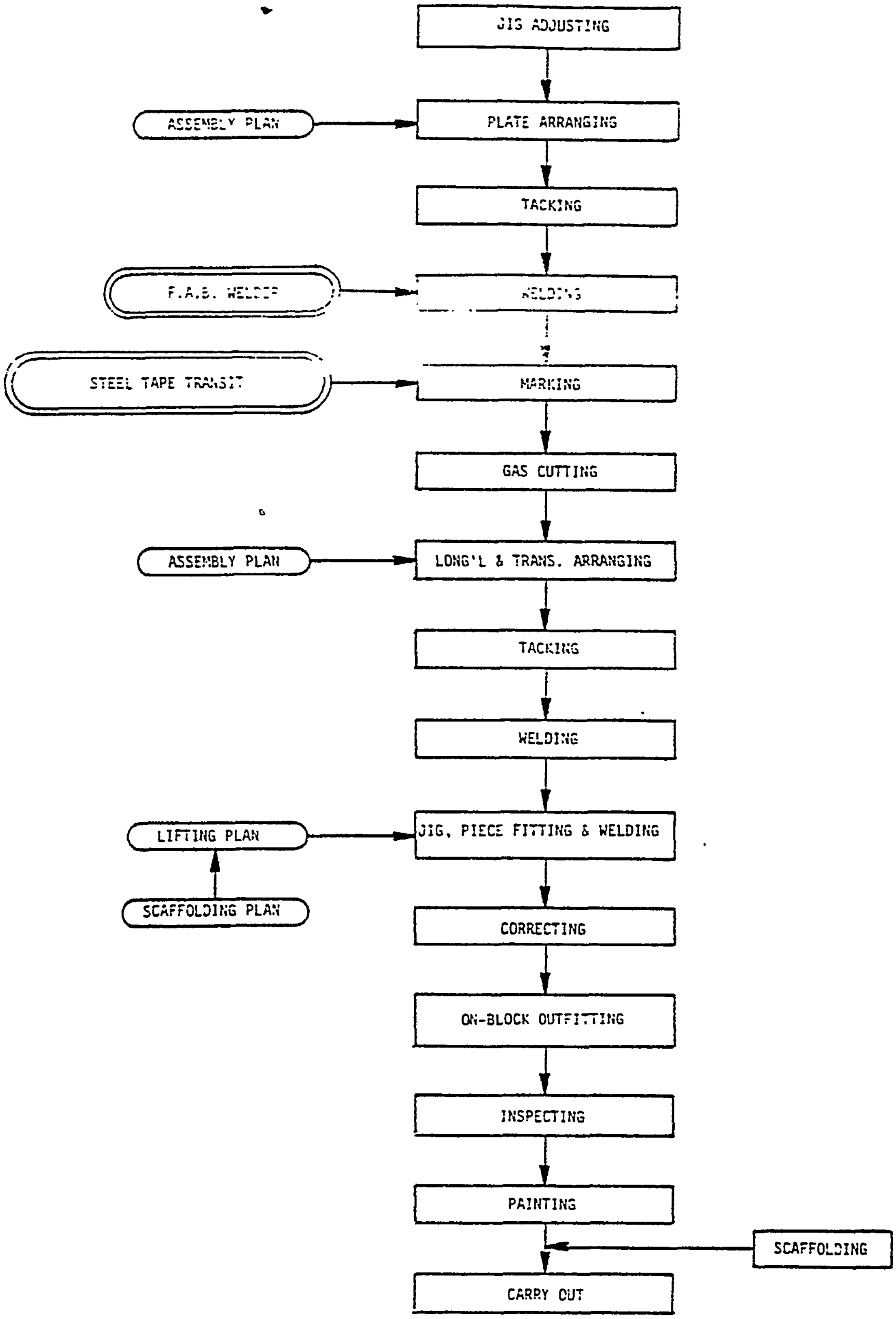

FLOW CHART OF SUBASSEMBLY

FIGURE 3-9



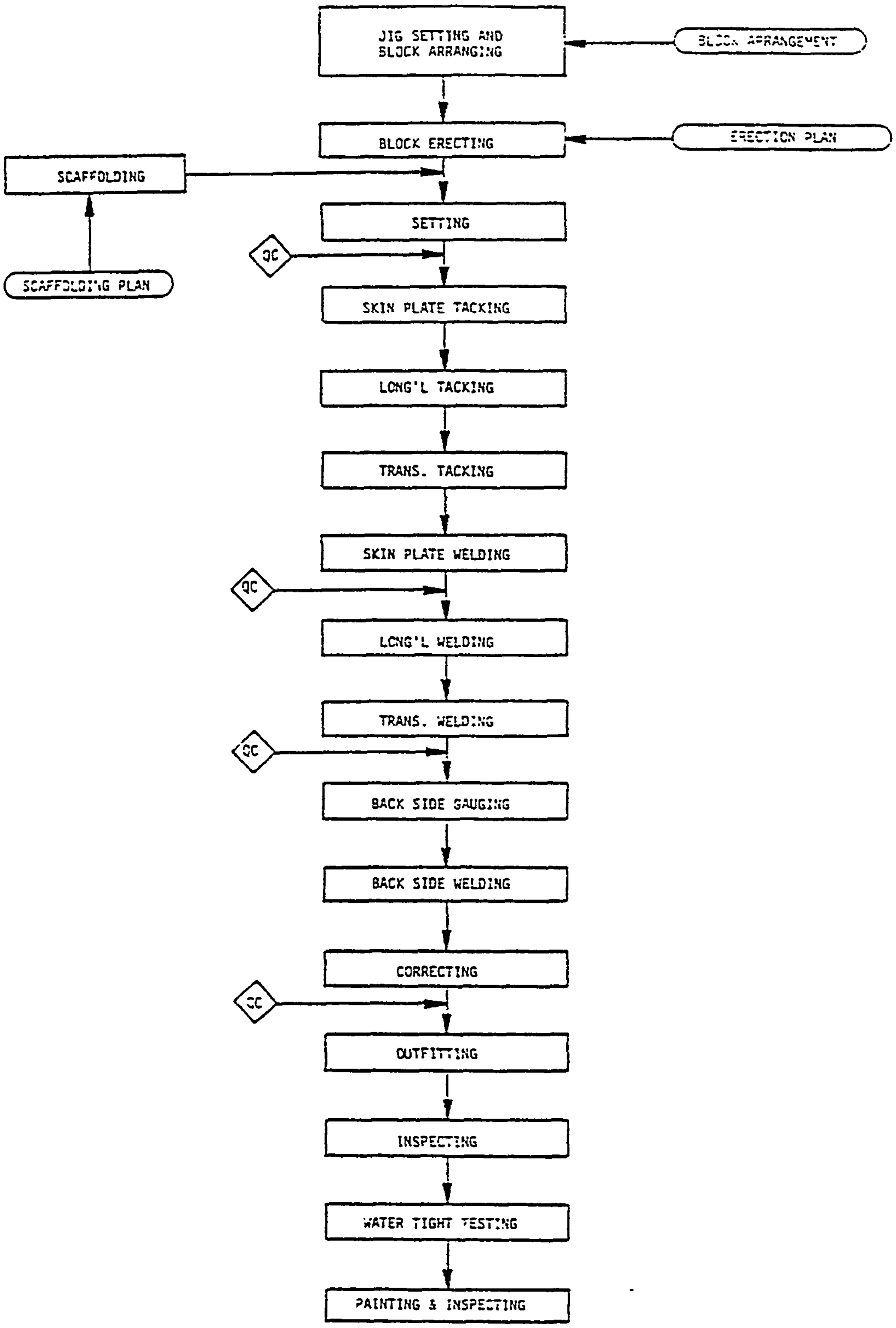

FLOW CHART OF FLAT PANEL ASSEMBLY

FIGURE 3-10




FLOW CHART OF CURVED PANEL ASSEMBLY

FIGURE 3-11




FLOW CHART OF ERECTION

FIGURE 3-12

Erection

Erection work flow is described from the jig arrangement to the final paint and inspection step.

Marking and Cutting

The relationship of the marking and cutting functions to the mold loft and to production is shown in Figure 3-13. This chart illustrates the difference between the IHI and Levingston systems.

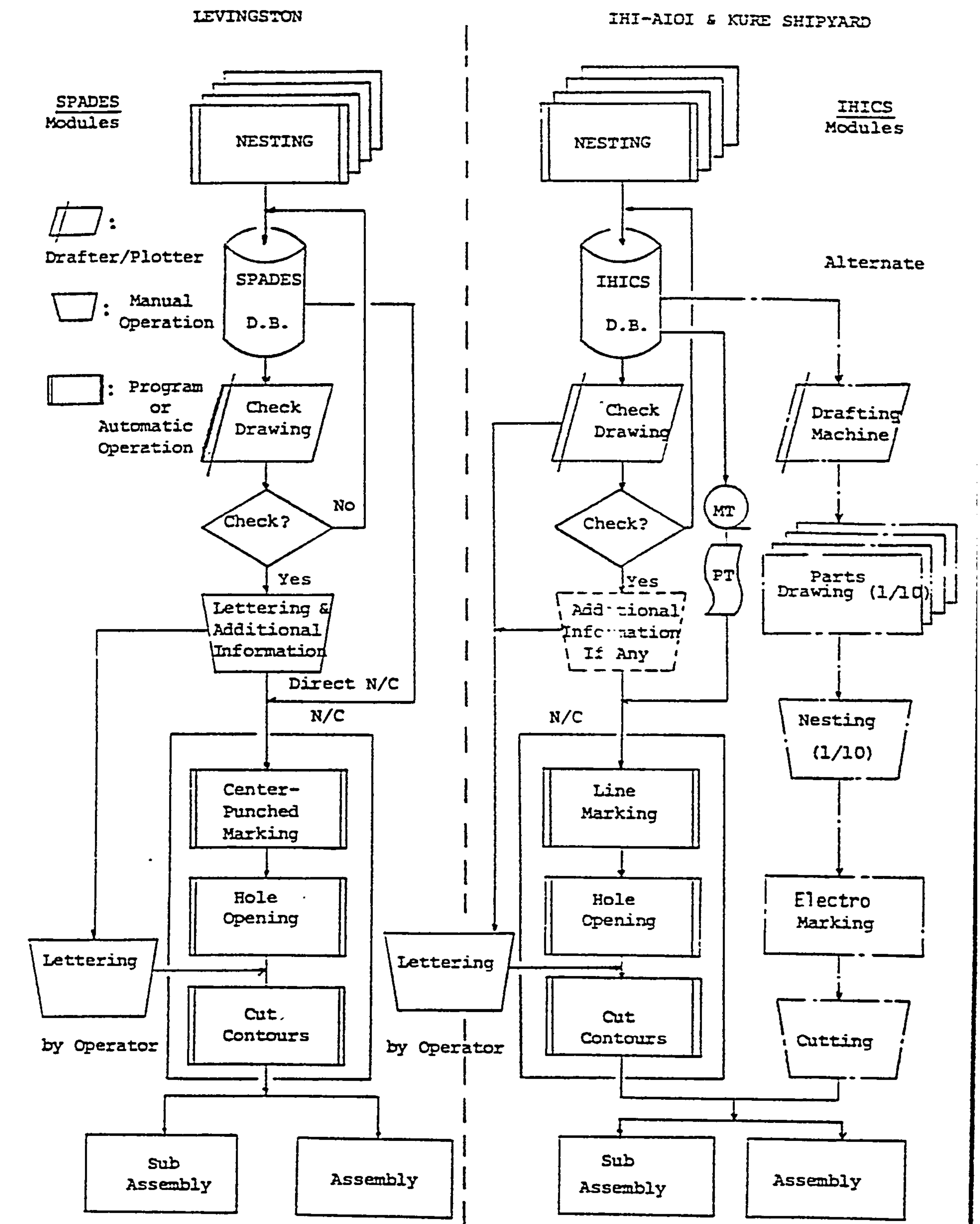
The choice of cutting machine for various component parts is shown in Table T3-1, which compares Levingston and IHI methods. A comparison of equipment available at Levingston and at the combined IHI facilities is shown in Table T3-2.

IHI's recommendations regarding cutting methods are given in Table T3-3. Levingston reviewed its utilization of cutting machines as a result of the IHT proposals. The N/C burner is now scheduled to cut complex and repetitive pieces requiring high precision. The 1:1 Optical Tracing Unit cuts small, repetitive pieces. The flame planer is used to rip flanges and web frames. The material flow arrangement for the N/C machine recommended by IHI at Levingston is shown in Figure 3-14. This layout and fabrication process is based on the assumption that the N/C machine would produce all cut plate except small pieces such as brackets, ribs, etc.

Panel Line

IHI has two "flat plate" panel lines located within the No. 2 and No. 3 Assembly Shops. Lay out and material flow patterns within these shops is illustrated in Figure 3-15

The decision to build an enclosed panel line facility at Levingston was made prior to the arrival of IHI consultants.




COMPARISON OF N/C WORKS FLOW

FIGURE 3-13

## TABLE T3-1

## OBJECTIVE HULL PIECES FOR N/C MACHINE

| Objective Pieces \ Company | LEVINGSTON | IHI-AIOI SHIPYARD (F-32) |
|---|---|---|
| WEB PLATE (HOLD) | N/C BURNING | N/C BURNING<br>117 PLT |
| FLOOR PLATE (HOLD) | | |
| MAIN GIRDER | | |
| WEB PLATE (OTHERS)<br>FLOOR PLATE (OTHERS)<br>GIRDER (OTHERS)<br>BKT | | N/C DRAWING<br>↓<br>Electro Marking<br>↓<br>HAND CUTTING<br>622 PLT* |
| CURVED SHELL | | N/C BURNING<br>240 PLT |
| FLAT SHELL<br>FLAT DECK<br>FLAT WALL<br>FLAT BULKHEAD | | FLAME PLANER<br>606 PLT |
| FLAT BAR<br>FACE PLATE | MATERIAL CUTTING LIST<br>↓<br>HAND MARKING<br>↓<br>HAND CUTTING | N/C DRAWING<br>Electro Marking<br>HAND CUTTING<br>*Included Above * |
| FLAT SHAPE | | MATERIAL CUTTING LIST<br>HAND MARKING 1900 P<br>HAND CUTTING |
| CURVED SHAPE | | |
| COLLAR PLATE, ETC. | SHEARING OR<br>N/C BURNING OR<br>HAND CUTTING | MAGNET TRACER OR<br>PHOTO TRACER |

1) Numbers in IHI's columns are the actual numbers of plates for a "Future-32" constructed at IHI AIOI Shipyard.

## TABLE T3-2

## COMPARISON TABLE OF N/C BURNING MACHINE BETWEEN LSCo & IHI

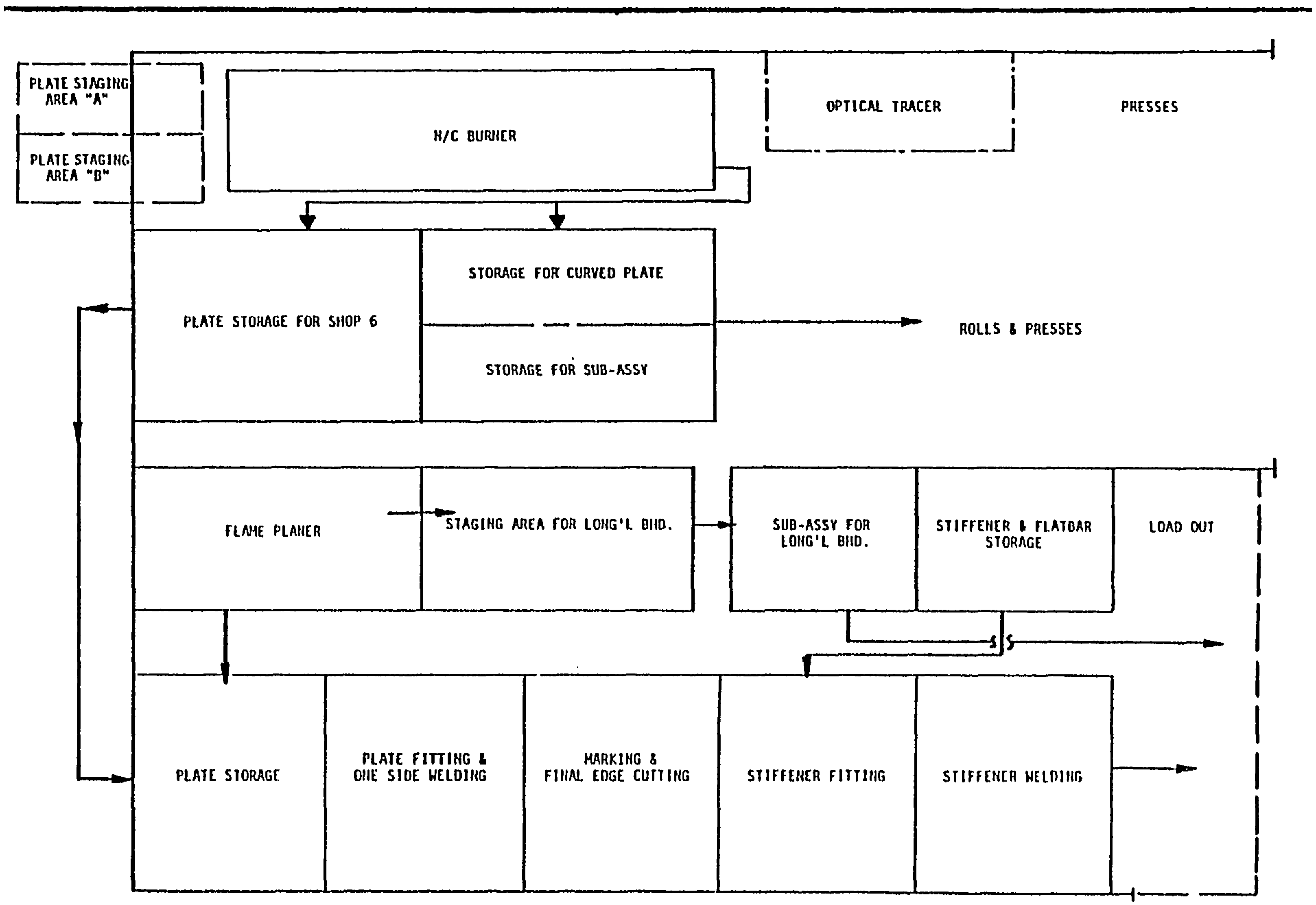
| | | ITEM \ COMPANY | LEVINGSTON | IHI | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | FUNCTION | All ROUND | ALL ROUND | SIMPLE | MARKING | ALL ROUND | ALL ROUND | MULTI.TORCH |
| INSTALLATION DATE | | | April, '75 | Oct., '71 | Sept., '72 | April, '75 | 1974 | Aug., '71 | Sept., '74 |
| MAKER | | Burning Machine | CRO N/C 3000 | Koike,Japan | Tanaka,Japan | Tanaka,Japan | Tanaka,Japan | Tanaka,Japan | Koike,Japan |
| MAKER | | Controller | Kongsberg CNC 500 | Toshiba T-1500C | Toshiba T-1300S | IHI MF-240M | Toshiba T-1500 | Toshiba T-1500 | Toshiba T-40 |
| CAPACITY | BURNING MACHINE | Effective Rail Span | 29'-7" | 31'-2" | 18'-2" | 16'-3" | 39'-0" | 58'-6" | 16'-9" |
| CAPACITY | BURNING MACHINE | Effective Rail Length | 111'-0" | 56'-3" | 74'-8" | 74'-8" | 97'-6" | 73'-2" | 58'-6" |
| CAPACITY | BURNING MACHINE | Weight | | 10 MT | 2 MT | 0.7 MT | 8 MT | 13 MT | 1.5 MT *3 |
| CAPACITY | BURNING MACHINE | Gas Pressure Used | $O_2$: 120 PSI Natural Gas: 15 PSI | $O_2$: 9kg/$cm^2$ LPG 65kg/$cm^2$ | → | | → | → | → |
| CAPACITY | BURNING MACHINE / SPEED | Cutting | 2-50 IPM/15-250IPM | 0.4-60 IPM | 2-51 IPM | | 0.4-118 IPM | → | → |
| CAPACITY | BURNING MACHINE / SPEED | Marking | 20.83'/Min. | 39'/Min. | 19.5'/Min. | 58.5'/Min. | 39'/Min. | → | → |
| CAPACITY | BURNING MACHINE / SPEED | Rapid Transverse | 20.83'/Min. | 39'/Min. | 19.5'/Min | 58.5'/Min. | 39'/Min. | → | → |
| CAPACITY | BURNING MACHINE | Marking Precision | | ± 1/64" | → | ± 1.5/64" | ± 1/64" | → | → |
| CAPACITY | BURNING MACHINE | Gas Used | Natural Gas | LPG | → | → | → | → | → |
| CAPACITY | BURNING MACHINE / TORCH BLOCK | Torch Station | 6(2 Master, 4 Slave) | 4 | 3 | 1 | 2 | 3 | 3 |
| CAPACITY | BURNING MACHINE / TORCH BLOCK | Bevel | I.K.Y.X.Y | I.K.Y.X.Y | I | | I | I.Y.Y | I |
| CAPACITY | BURNING MACHINE / TORCH BLOCK | Nozzle Tip | Oxweld Made | IHI Made | Koike 106PD | Tanaka | Tanaka 3155A | Tanaka-Curtain | Tanaka-Curtain |
| CAPACITY | BURNING MACHINE / TORCH BLOCK | Height Sensing | Fluidic | Fluidic | Fluidic | | Fluidic | Roller | Roller |
| CAPACITY | BURNING MACHINE / TORCH BLOCK | Rotating Torch | Equipped | Equipped | | | | Equipped | Equipped |
| CAPACITY | BURNING MACHINE / TORCH BLOCK | Ignition Extinguish | Automatic | Automatic | Manual | Automatic | Automatic | Automatic | Manual |
| CAPACITY | BURNING MACHINE / TORCH BLOCK | Piercing | Automatic | Automatic | → | | → | → | → |
| CAPACITY | BURNING MACHINE / TORCH BLOCK | Marking | Center-punched | Plastic Burned | Zinc Burned | → | → | → | Plastic Burned |
| CAPACITY | BURNING MACHINE | Driving Motor | D.C. Servo | D.C. Servo | → | → | → | → | → |
| CAPACITY | CONTROLLER | Control Axis | X.Y.θ | X.Y1-2.θ1-2 | X.Y | X.Y | X.Y | X.Y.θ | X.Y.θ |
| CAPACITY | CONTROLLER | Minimum Dimension Input | 1/64" | 0.1/64" | → | → | → | → | → |
| CAPACITY | CONTROLLER | Maximum Dimension Input | 120' | 1230' | → | → | → | 123' | 1230' |
| CAPACITY | CONTROLLER | Tape Format | ESSI | EIA-8U | → | → | → | → | → |
| CAPACITY | CONTROLLER | Interpolation | Linear and Circular | Linear & Cir. | → | → | → | → | → |
| CAPACITY | CONTROLLER | Kerf Compensation | Dial Set | Dial Set | | | Dial Set | → | → |
| CAPACITY | CONTROLLER | Reversing | Direct on Path Program Rev. | Dir.on Path Prog. Rev. | → | → | → | → | → |
| CAPACITY | CONTROLLER | Auxi. Function | | 36 | 28 | 32 | 33 | 51 | 27 |
| CAPACITY | CONTROLLER | Others | | | | | | | |
| | | | | | | | | | |
| PAST RECORD | | | | | | | | | |
| PAST RECORD | CUTTING SPEED | 3/8" T 5/8" | Variable | 51 IPM | 24 IPM | | 30 IPM | 28 IPM | 24 IPM |
| PAST RECORD | CUTTING SPEED | 5/8" T 3/4" | Variable | 47 IPM | 20 IPM | | 26 IPM | 26 IPM | 22 IPM |
| PAST RECORD | CUTTING SPEED | 3/4" T 7/8" | Variable | 31 IPM | 16 IPM | | 22 IPM | 24 IPM | 20 IPM |
| PAST RECORD | CUTTING SPEED | 7/8" T | Variable | 31 IPM | 15 IPM | | 20 IPM | 20 IPM | 18 IPM |
| PAST RECORD | | Consideration for Torsion | Water Cooling Cutting Seq., Bridging | Cutting Seq. Wtr. Cooling | → | | → | → | Cutting Seq. Bridging |
| PAST RECORD | | Troubles Up-to-date | | | | | | | |
| ADMINISTRATION | MAINTENANCE | Daily | Electronic Tech. | Operator | → | → | → | → | → |
| ADMINISTRATION | MAINTENANCE | Periodical | Electronic Tech. | 2 Times/Yr. Maker | → | → | → | → | → |
| ADMINISTRATION | MAINTENANCE | Repairing | Maker & Elect.Tech. | Maker IHI Specialist | → | → | → | → | → |
| ADMINISTRATION | OPERATOR | Number | 3 | 2 | 2 | 2 | 4 | 4 | 1 |
| ADMINISTRATION | OPERATOR | Experience | 4-5 years | 2-3 Years | 3.5 Yrs. | 1.5 Yrs. | 1.5 Yrs. | 3 Yrs. | 1.5 Yrs. |
| Max. Plate No. to be Cut Simultaneously | | | 4 PL(12'-0"×50'-0") | 2 PL(12'×34') | 1 PL(15'×75') | 1 PL(15'×75') | 2PL(11'9"×98') | 3PL(16'×46') | 1PL(12'×9') |
| REMARKS | | | DNC | Tokyo - 1 Chita - 1 AIOI - 1 | Chita - 1 | Chita - 1 Yokohama-2 | Chita - 2 AIOI - 2 | Kure - 2 | Kure - 2 |

## TABLE T3-3

## TABLE OF EFFECTIVE CUTTING MACHINES

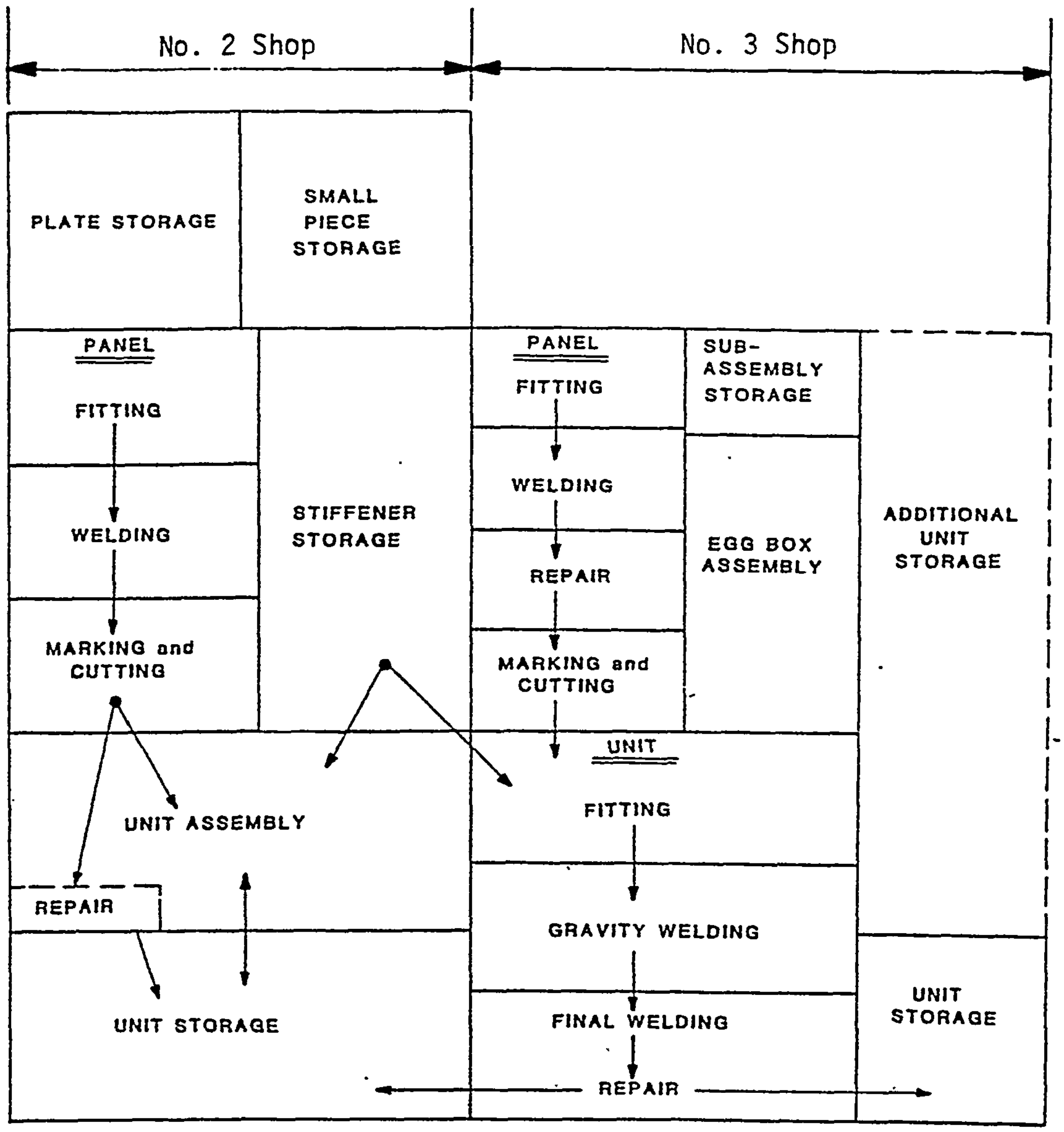
| CUTTING STAGE | CATEGORY OF PIECES | EFFECTIVE CUTTING MACHINE | METHOD | RECOMMENDED SELECTION FOR LSCo | |
|---|---|---|---|---|---|
| Long'l & FB | Long'l | Automatic Long'l cutting machine & semi-automatic machine | Butt: Automatic Long'l Cutter<br>Slot Hole: Semi-automatic machine | X | 1. Auto machine is not completely implemented.<br>2. Auto machine is not cost-effective due to low volume. |
| | | Manual & semi-automatic machine | Butt: Manual<br>Slot Hole: Semi-auto machine | O | |
| | Flat Bar | Automatic Long'l cutting machine & semi-automatic | Butt: Automatic long'l cutter<br>Slot Hole: Semi-auto machine | X | |
| | | Manual & semi-automatic machine | Butt: Manual<br>Slot Hole: Semi-auto machine | O | |
| Curved Plates | Curved Plates | NC Gas Cutter | NC Marking → NC Gas Cutter | O | 1. Because of few manhours. |
| | | Semi-automatic machine | Manual Marking → Semi-auto machine | X | |
| Internals | Floor & long'l Bhd with few edge preparation or no edge preparation | NC Plasma Cutter | NC Marking → NC Plasma Cutter | O | 1. Because of more precise accuracy.<br>2. Because of few manhours. |
| | | NC Gas Cutter | NC Marking → NC Gas Cutter | O | |
| | | Semi-automatic machine | EPM-Marking → Semi-auto machine<br>Photo-Marking → Semi auto machine<br>Manual-Marking → Semi-auto machine | X | |
| | Floor & long'l Bhd with edge preparation | NC Gas Cutter | NC Marking → NC Gas Cutter | O | In Japan O and X are reverse. But in U.S., NC gas cutter is better due to awkward manual cutting & less investment. |
| | | Semi-automatic machine | EPM-Marking → Semi-auto machine<br>Photo-Marking → Semi-auto machine<br>Manual-Marking → Semi-auto machine | X | |
| | Small Pieces | NC Plasma Cutter | NC Marking → NC Plasma Cutter | O | More Speedy and less shrinkage than NC Gas Cutter. |
| | | NC Gas Cutter | NC Marking → NC Gas Cutter | A | |
| | | Semi-automatic machine | EPM-Marking → Semi-auto machine<br>Photo-Marking → Semi-auto machine<br>Manual-Marking → Semi-auto machine | X | In U.S., manual cutting is awkward. |
| | Small pieces which are usually cut out from scrap | Optical Tracer | | O | |
| | | NC Plasma Cutter | Small pieces are put in between big pieces. After big pieces are cut, they are manually or automatically cut. | O | |
| | | NC Gas Cutter | | O | |
| | | Semi-auto machine | Manual-Marking → Semi-auto machine | X | |
| Panel | Panel Plate | Flame Planer | Manual-Marking → Plane cutter<br>EPM-Marking → Plane cutter<br>Photo-Marking → Plane cutter | O | Manual marking = low manhours. |
| | | Semi-automatic machine | Manual-Marking → Semi-auto machine | X | |

O: Suitable
A: Fair
X: Unsuitable




IHI PROPOSED LAYOUT - SHOPS 5 & 6

FIGURE 3-14




IHI PANEL LINES

FIGURE 3-15

However, their assistance in this area influenced the proposed lay out and material flow within Shop 5 (Fabrication) and Shop 6 (Panel Line), and utilization of the machines within these shops.

The lay out and material flow proposed to Levingston by IHI was shown on Figure 3-14. The arrangement decided upon by Levingston, shown in Figure 3-16 is similar to IHI's proposal.

Sand Blasting/Shot Blasting

The general flow of painting work at IHI is described in the flow chart of Figure 3-17. Sketches of each enclosed painting facilities are provided on Figures 3-18 through 3-21.

IHI introduced to Levingston the concept of painting units at the assembly stage prior to erection, which has resulted in considerable savings, estimated to be about 40 per cent per unit. Savings resulted from less time moving labor and materials to the work place, fewer cramped work spaces, better supervision, less scaffolding requirements, and fewer premium hours caused in attempts to avoid disturbing other trades.

## OUTFITTING

The basic production process is illustrated schematically in Figure 3-22. This chart depicts inputs and outputs in terms of tonnage and labor man hours used. The evidence of a high amount of "pre-outfitting" can be determined from the data given. The pre-outfitting composes 73 per cent by weight, and 27 per cent by labor man hours, of the total for outfitting.

The total outfitting process is shown in Figure 3-23. This chart illustrates the importance of composite drawings and of palletizing

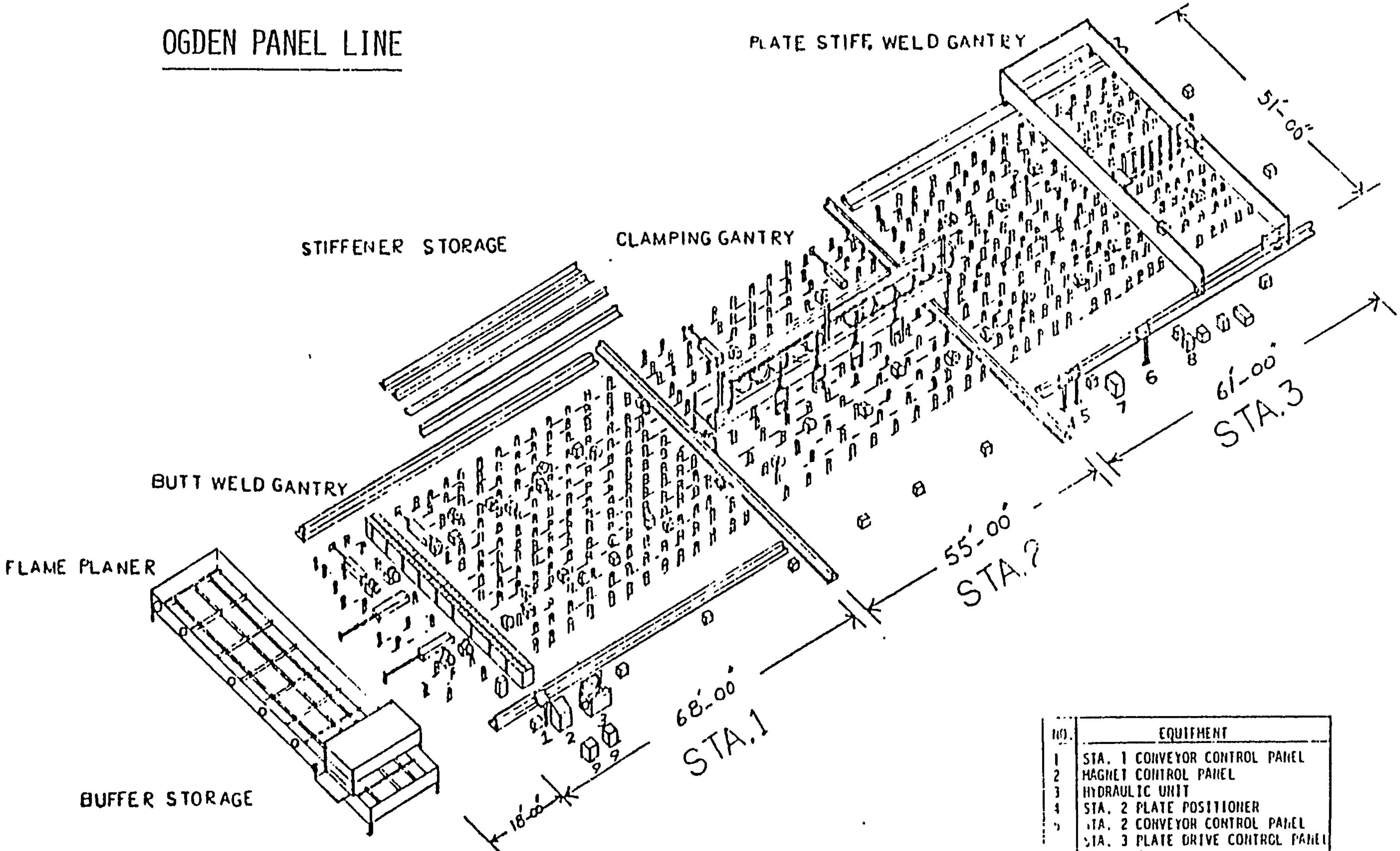
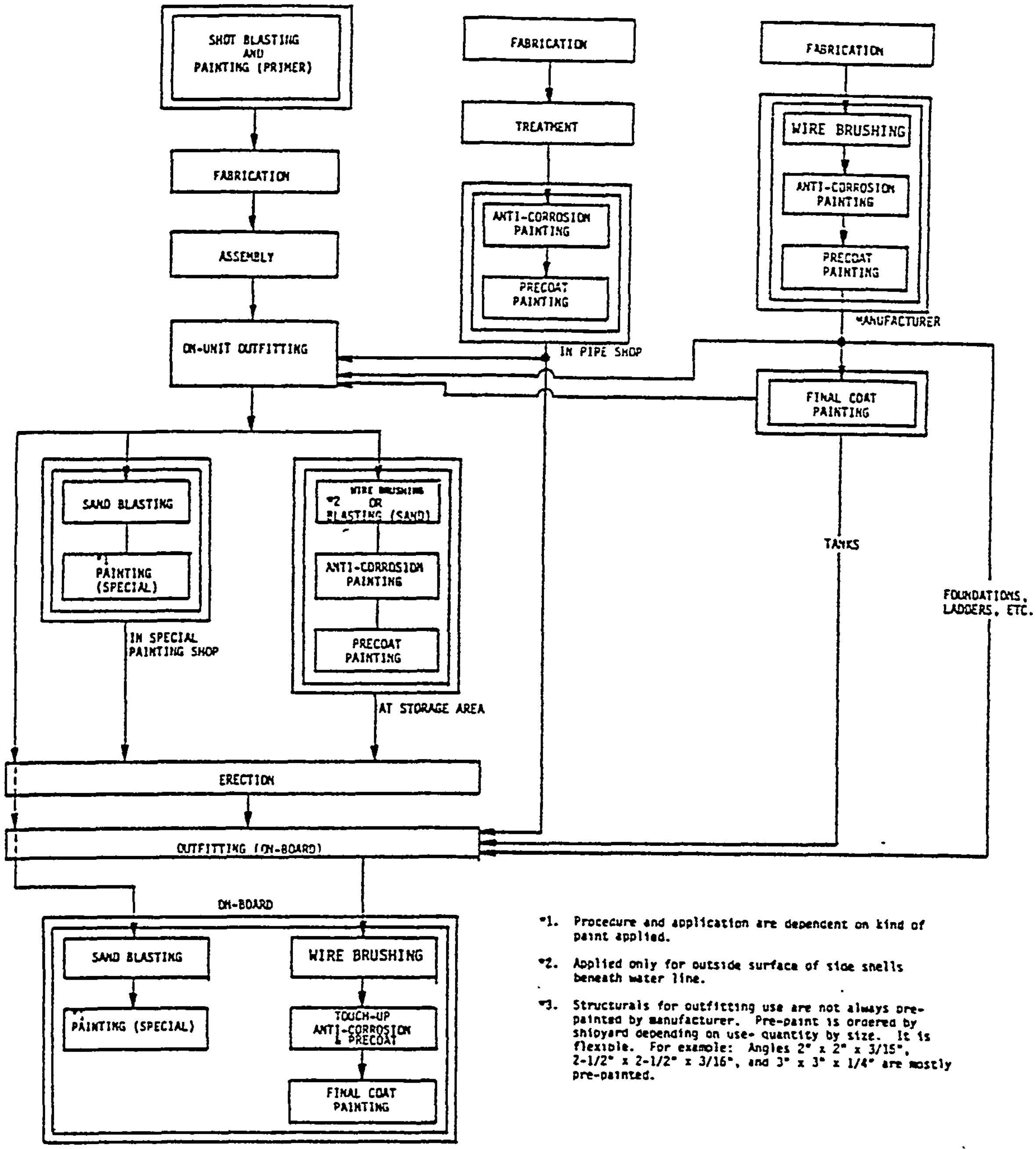



FIGURE 3-16

| NO. | EQUIPMENT |
|---|---|
| 1 | STA. 1 CONVEYOR CONTROL PANEL |
| 2 | MAGNET CONTROL PANEL |
| 3 | HYDRAULIC UNIT |
| 4 | STA. 2 PLATE POSITIONER |
| [illegible] | STA. 2 CONVEYOR CONTROL PANEL |
|  | STA. 3 PLATE DRIVE CONTROL PANEL |
| [illegible] | 460 V.3Ø |
| [illegible] | 6 - 600 AMP. W/M |
| [illegible] | 2 - 1200 AMP. W/M |



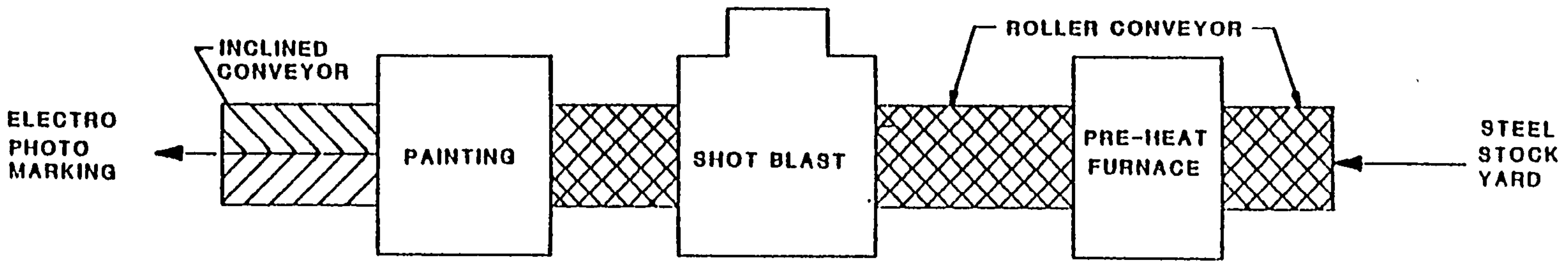

*1. Procedure and application are dependent on kind of paint applied.

*2. Applied only for outside surface of side shells beneath water line.

*3. Structurals for outfitting use are not always pre-painted by manufacturer. Pre-paint is ordered by shipyard depending on use- quantity by size. It is flexible. For example: Angles 2" x 2" x 3/15", 2-1/2" x 2-1/2" x 3/16", and 3" x 3" x 1/4" are mostly pre-painted.

GENERAL WORK FLOW

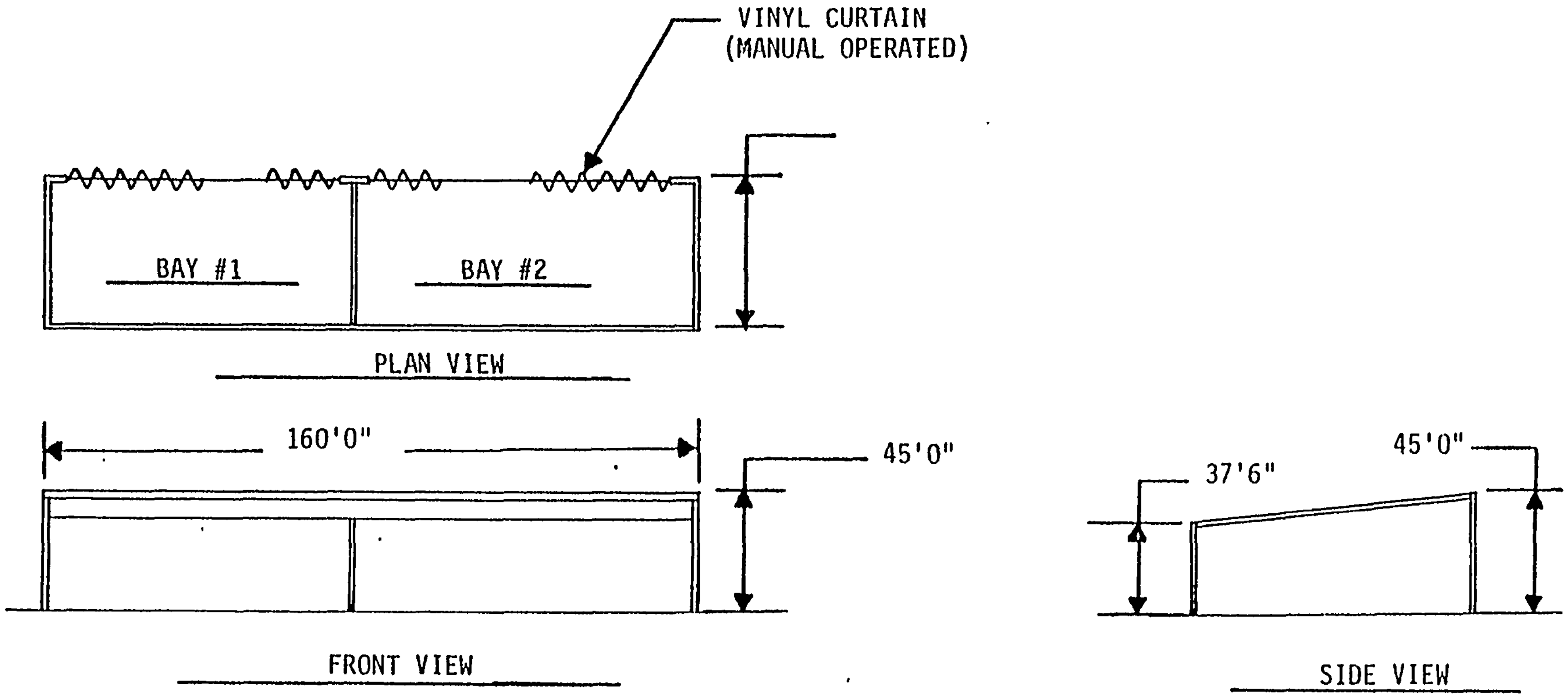
FIGURE 3-17




FABRICATION SHOP

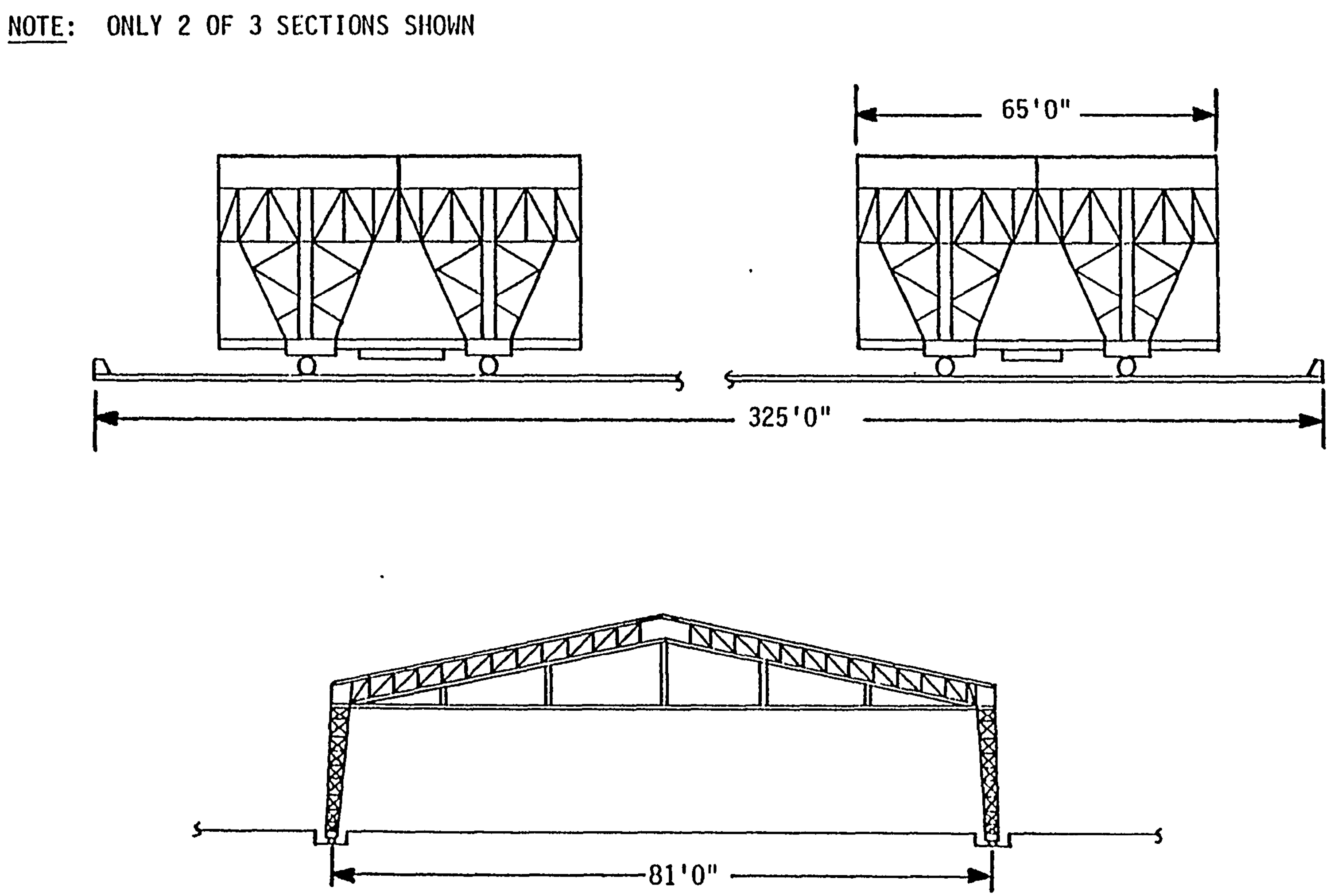
SHOT BLAST FACILITY

FIGURE 3-18




NO. 1 BLOCK PAINTING BUILDING

FIGURE 3-19

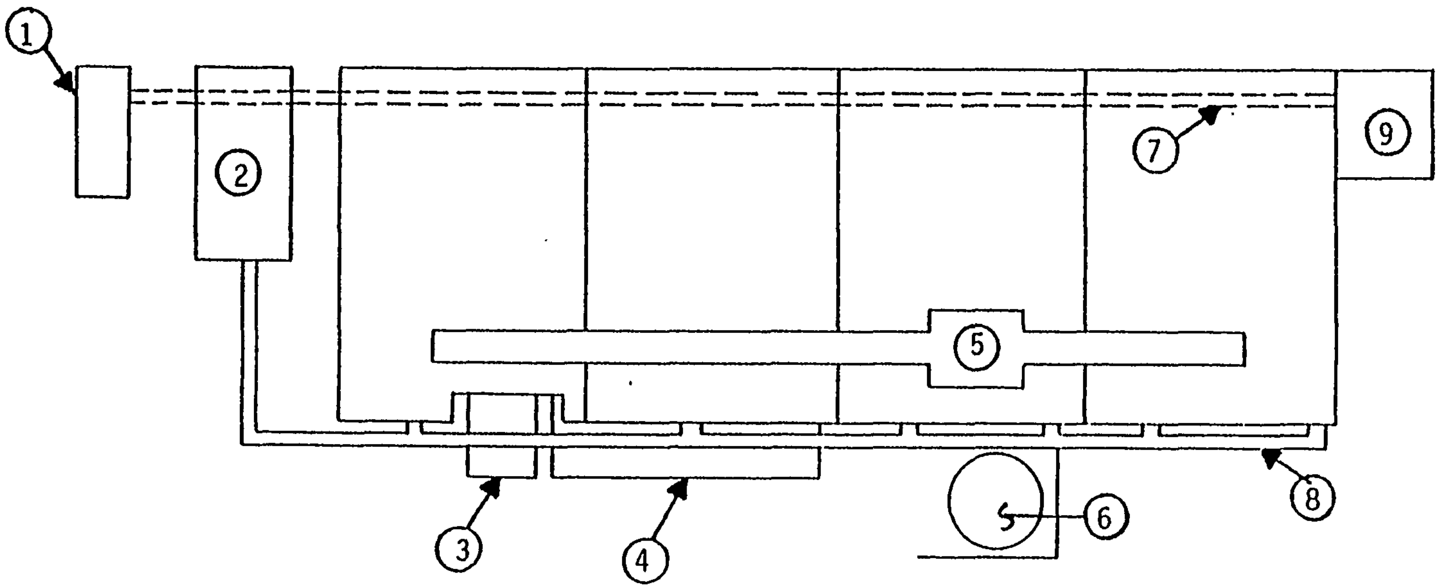



NO. 2 BLOCK PAINTING BUILDING

FIGURE 3-20

1 HEATED AIR UNIT
2 DUST COLLECTOR
3 CLEAN SAND HOPPER
4 CLEAN SAND CONVEYOR
5 SAND COLLECTION PIT

6. USED SAND HOPPER
7. HEATED AIR DUCT,
8. EXHAUST DUCT
9. HEATED AIR UNIT



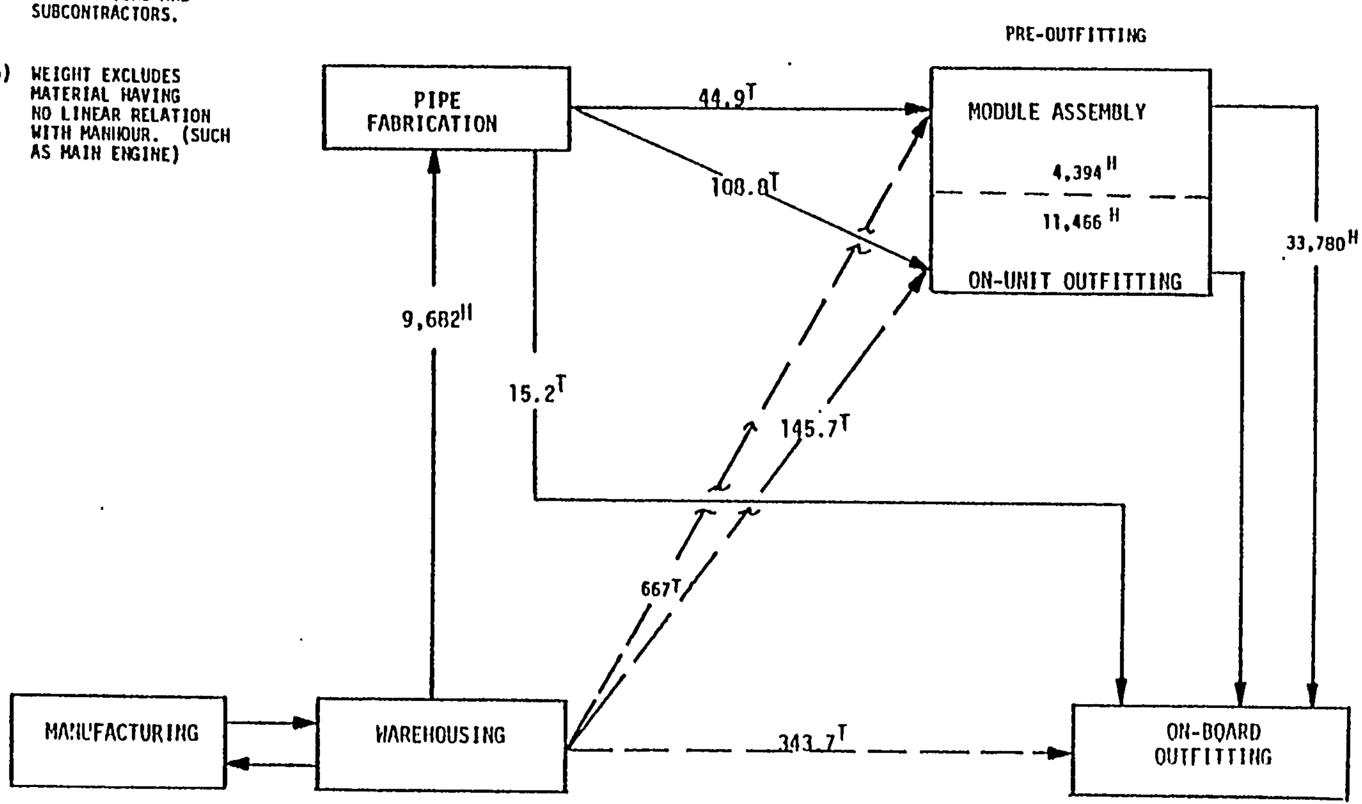

SPECIAL PAINT SHOP

FIGURE 3-21

NOTE

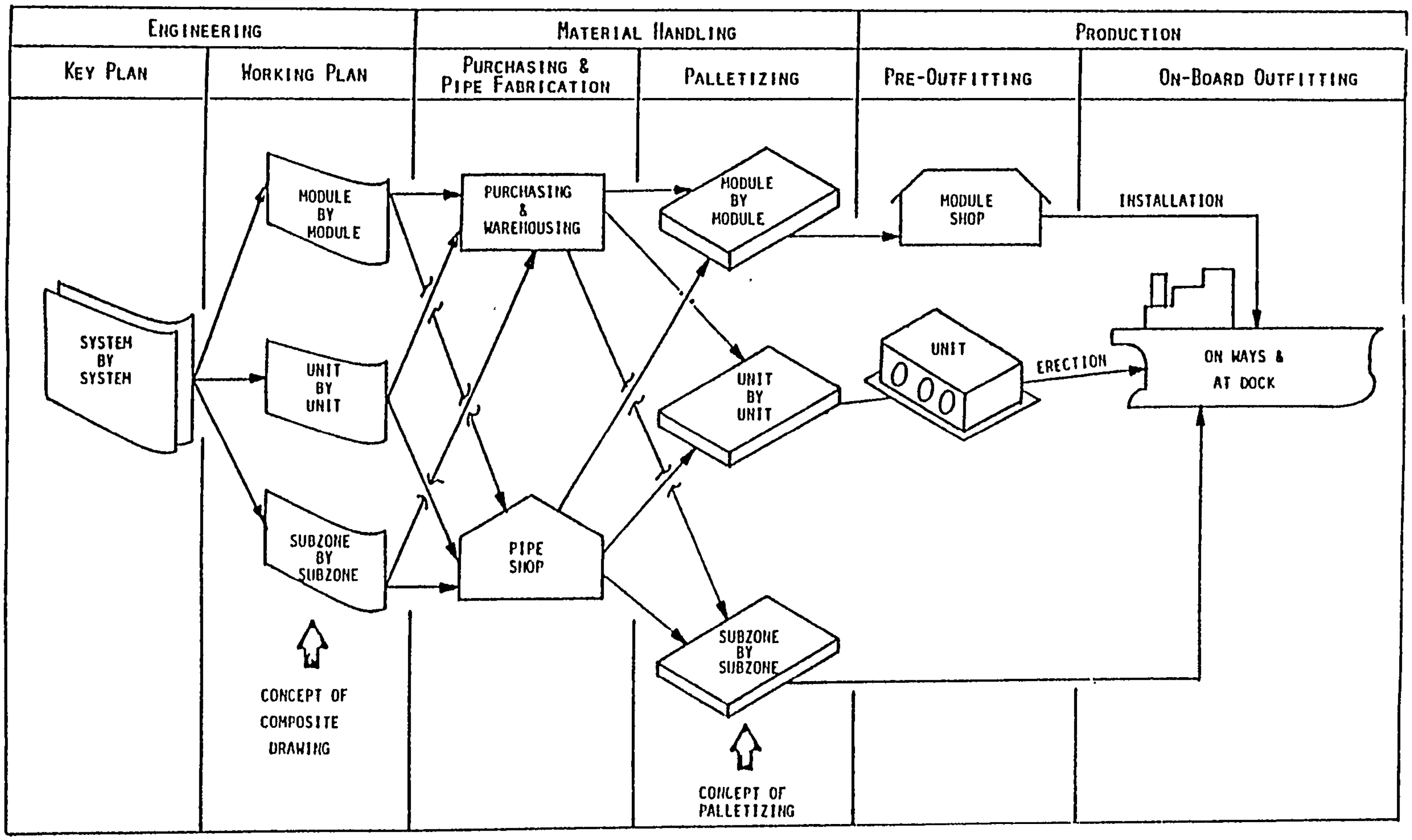
a) EXCLUDING MANHOURS FOR PAINTING AND SUBCONTRACTORS.

b) WEIGHT EXCLUDES MATERIAL HAVING NO LINEAR RELATION WITH MANHOUR. (SUCH AS MAIN ENGINE)




BASIC OUTFITTING PROCESS

FIGURE 3-22




TOTAL OUTFITTING PROCESS

FIGURE 3-23

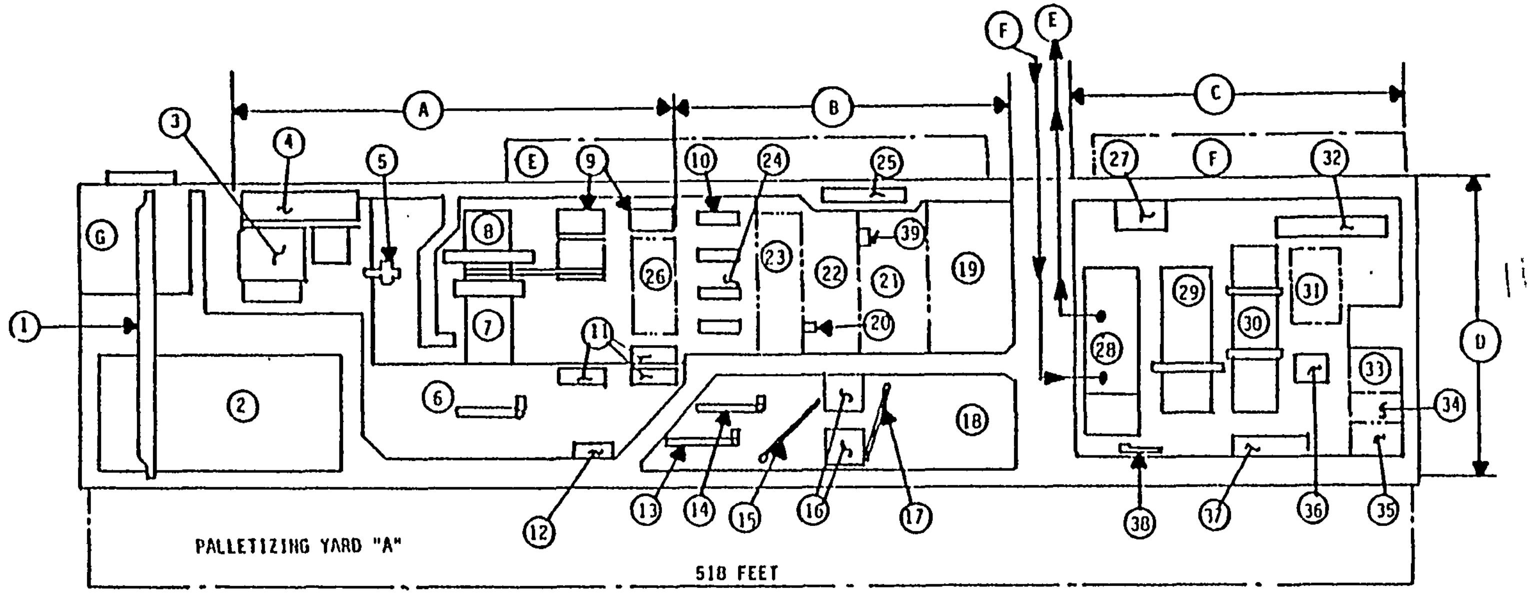
to the concept of effective pre-outfitting. The basic objective of this concept is to minimize on-board work, thereby shifting the work to more productive and safer conditions in shops and on land.

Pipe Fabrication

IHI practices mass production, assembly line and automated methods in its pipe fabricating process. The layout and flow of work in the pipe shop is indicated in Figure 3-24. This sketch shows that pipe fabrication work is performed in separate sections of the shop according to pipe size, with 3" pipe size being the dividing line. A full process line is available at each separate location in this shop for the size pipe being fabricated, with the exception of pipe bending of large pipe, which is performed in a separate building. A schematic diagram of the pipe fabrication process in the small pipe lane section at IHI-Aioi is provided as Figure 3-25. Automation is employed at virtually every step in the pipe fabrication process, including transporting of pipe from station to station by conveyor. The type of bending to be applied on steel pipe is shown on Table T3-4.

The major recommendation made by IHI to Levingston concerning pipe fabrication was the fundamental change in concept between shop fabrication and on-board installation of pipe. Prior to TTP, Levingston performed virtually all pipe work on-board a vessel at the erection site. Much of the pipe fabrication was also performed on-board, by moving portable cutters, threaders, manual pipe benders, and bevel machines to the erection site. The pipe shop served as a place to perform some repetitive work and for pipe fabricating jobs done in inclement weather.

Consequently, IHI recommendations were directed at changing the whole system so that the pipe shop could serve as a true fabrication shop, including pipe assembly work.




A AUTOMATIC FABRICATION LINE - 2-1/2" & BELOW
B MANUAL FABRICATION LINE - 2-1/2" & BELOW
C MANUAL FABRICATION LINE - 3" & ABOVE
D 115 FEET
E PALLETIZING YARD "B"
F PALLETIZING YARD "C"
G OFFICE

1. OVERHEAD CRANE
2. STAGING AREA AFTER TREATMENT
3. AUTOMATIC PIPE RACKER
4. DIGITAL CUTTING
5. 2-POINT WELDER
6. N/C BENDER - TYPE 4
7. 4-POINT WELDER
8. 4-POINT ASSEMBLER
9. STORAGE RACKS
10. FITTING SLAB
11. STORAGE RACKS
12. STORAGE RACK
13. BENDER TYPE 2
14. BENDER TYPE 4
15. JIB CRANE
16. FITTING SLABS
17. JIB CRANE
18. FABRICATION AREA FOR PIPING MODEL
19. STAGING AREA
20. ROLLER & WELDER
21. FINISHING AREA
22. WELDING AREA
23. BUFFER ZONE
24. FABRICATION SLABS
25. ELECTRIC SUB-STATION
26. BUFFER ZONE
27. FABRICATION SLAB
28. PIPE RACK
29. MARKING RACK
30. WELDING AND STORAGE RACKS
31. MARKING & FINISHING AREA
32. FABRICATION SLAB
33. FINISHING AREA
34. BUFFER ZONE
35. WELDING AREA
36. FABRICATION SLAB
37. FABRICATION SLAB
38. PIPE COASTER
39. DRILLING MACHINE

IHI (AIOI) PIPE SHOP LAYOUT

FIGURE 3-24

## PIPE FABRICATION PROCESS (1/2"-2 1/2")

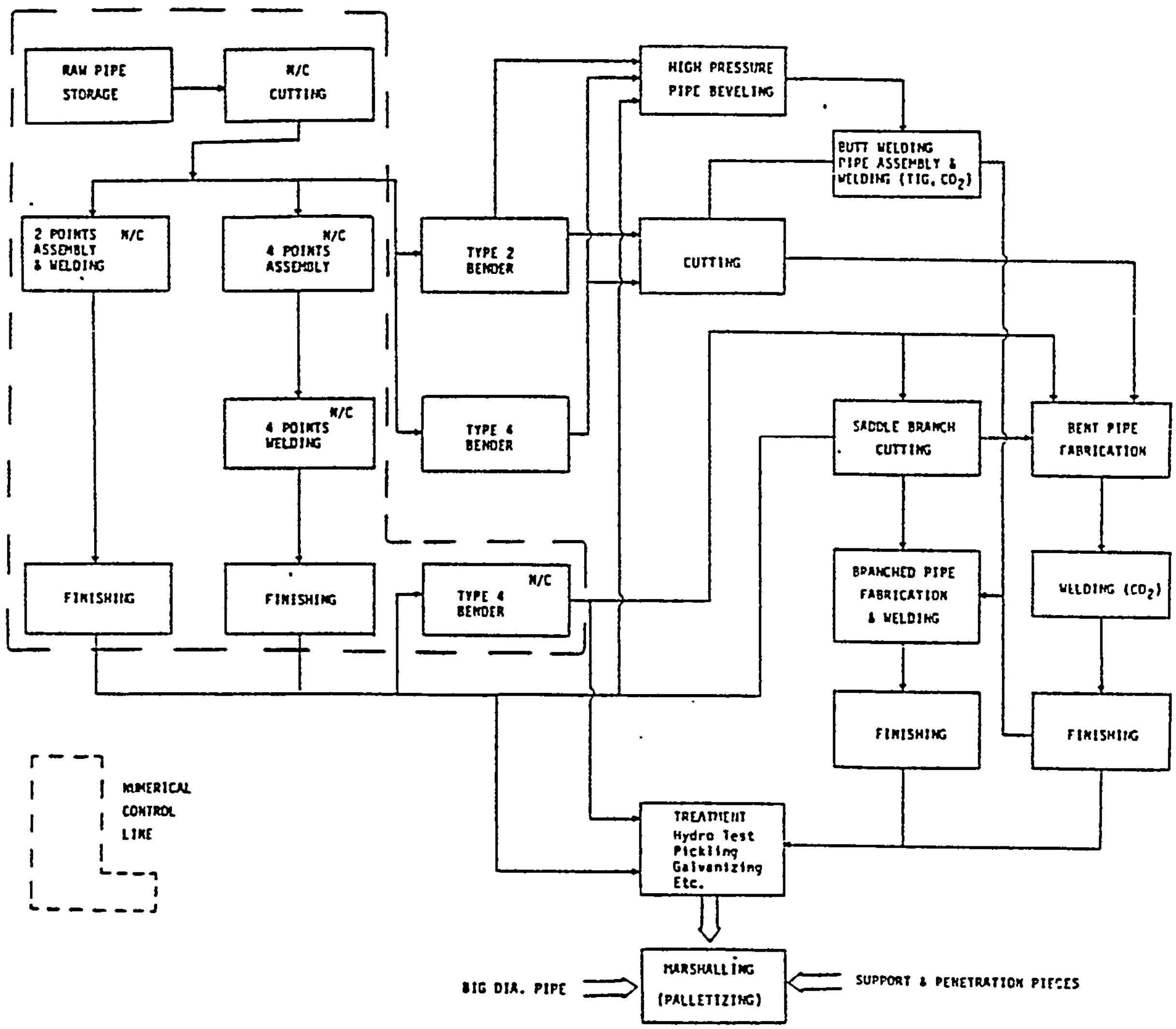



FIGURE 3-25

TABLE T3-4

PRODUCTIVITY COMPARISON

PREOUTFITTING VS. ONBOARD OUTFITTING

| Categories | | Parametric * Weight (T) | Manhour (H) | Efficiency (H/T) |
|---|---|---|---|---|
| On-Module | Main floor modules | 46.1 | 980 | 21.3 |
| | Modules with cooler flat | 6.2 | 190 | 30.6 |
| | Other modules | 40.0 | 484 | 12.1 |
| | Welding | - | 230 | - |
| | Crane operation | - | 170 | - |
| | Sub-total | 92.3 | 2054 | 21.6 |
| On-Unit | Inner bottom units | 4.3 | 215 | 50.0 |
| | L.E.F. & U.E.F. Units | 12.1 | 698 | 57.7 |
| | Main Deck Units | 16.7 | 782 | 46.8 |
| | in Casing | 16.9 | 979 | 57.9 |
| | Side Shell Units & Other Units | 17.5 | 525 | 30.0 |
| | Welding | - | 710 | - |
| | Sub-total | 67.5 | 3909 | 57.9 |
| | Preoutfitting Total | 159.8 | 5963 | 37.3 |
| On-Board | Piping | 18.7 | 3078 | 164.6 |
| | Steel Fitting | 21.5 | 2240 | 104.2 |
| | Others | 6.9 | 1430 | 207.2 |
| | Welding | - | 980 | - |
| | Sub-total | 47.1 | 7728 | 164.1 |
| | Grand Total | 206.9 | 13691 | 66.2 |

* Short ton: Weight of material such as pipes, valves, foundations, ventilation ducts, and so on, which are considered to have linear relation to manhour spent to install them.

The above table manifests the superiority of preoutfitting over onboard outfitting, i.e. on-module outfitting has 1/7 of on-board outfitting H/T, on-unit outfitting has 1/3, and totally preoutfitting has 1/4. Further 159.8 tons (77%) of total outfitting weight in engine room, 206.9 tons, is preoutfitted.

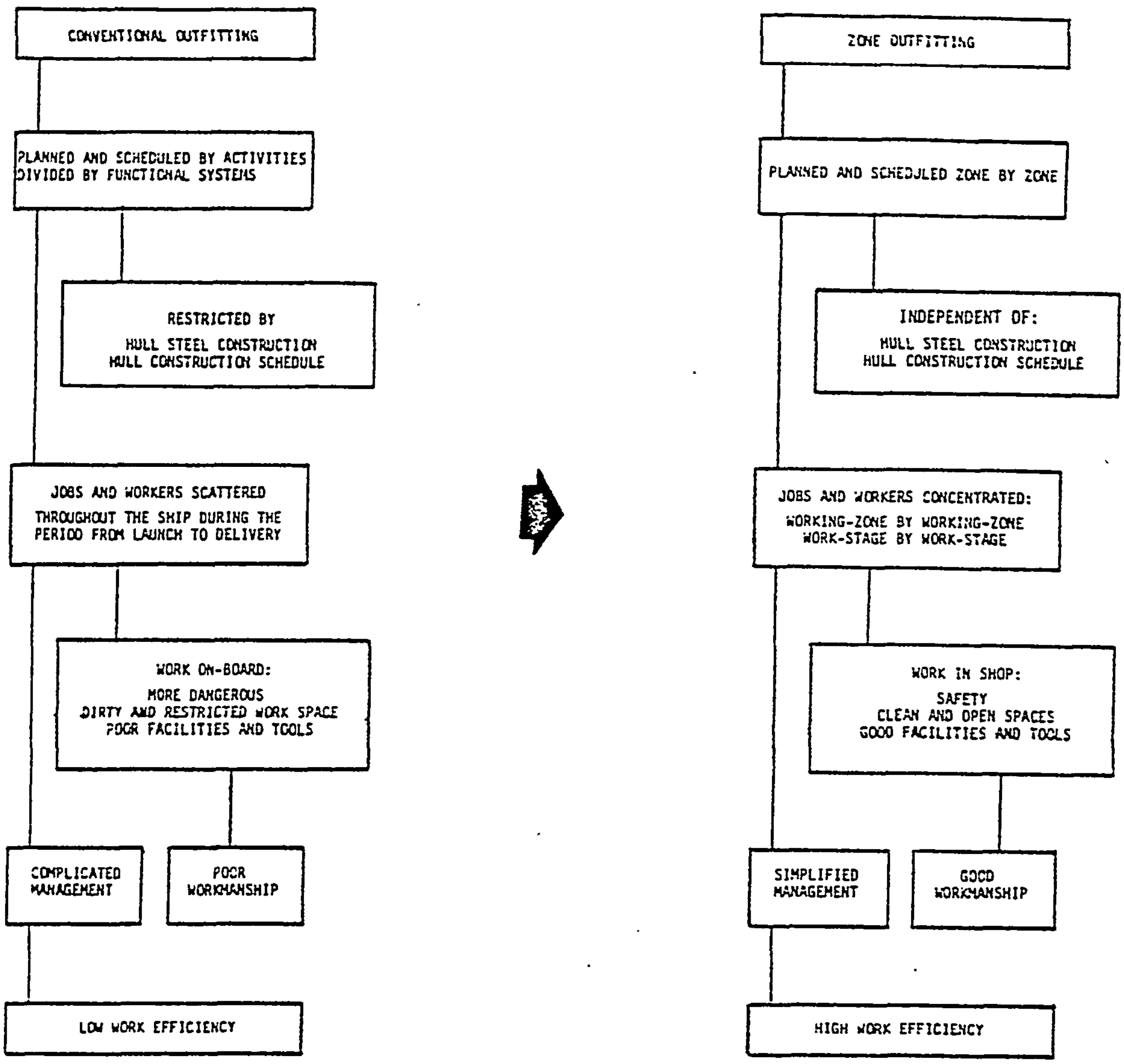
IHI recommended a new pipe shop for Levingston, with a layout utilizing the fabrication lanes concept. Further recommendations included increased automation and greater utilization of the computer in cutting and bending plans.

Levingston is still in the process of implementing systems and procedures to take advantage of the methods that can be adopted at low investment costs. The methods involving greater capital expenditure will be reviewed as the facilities, such as the proposed pipe shop, are implemented.

Zone Outfitting

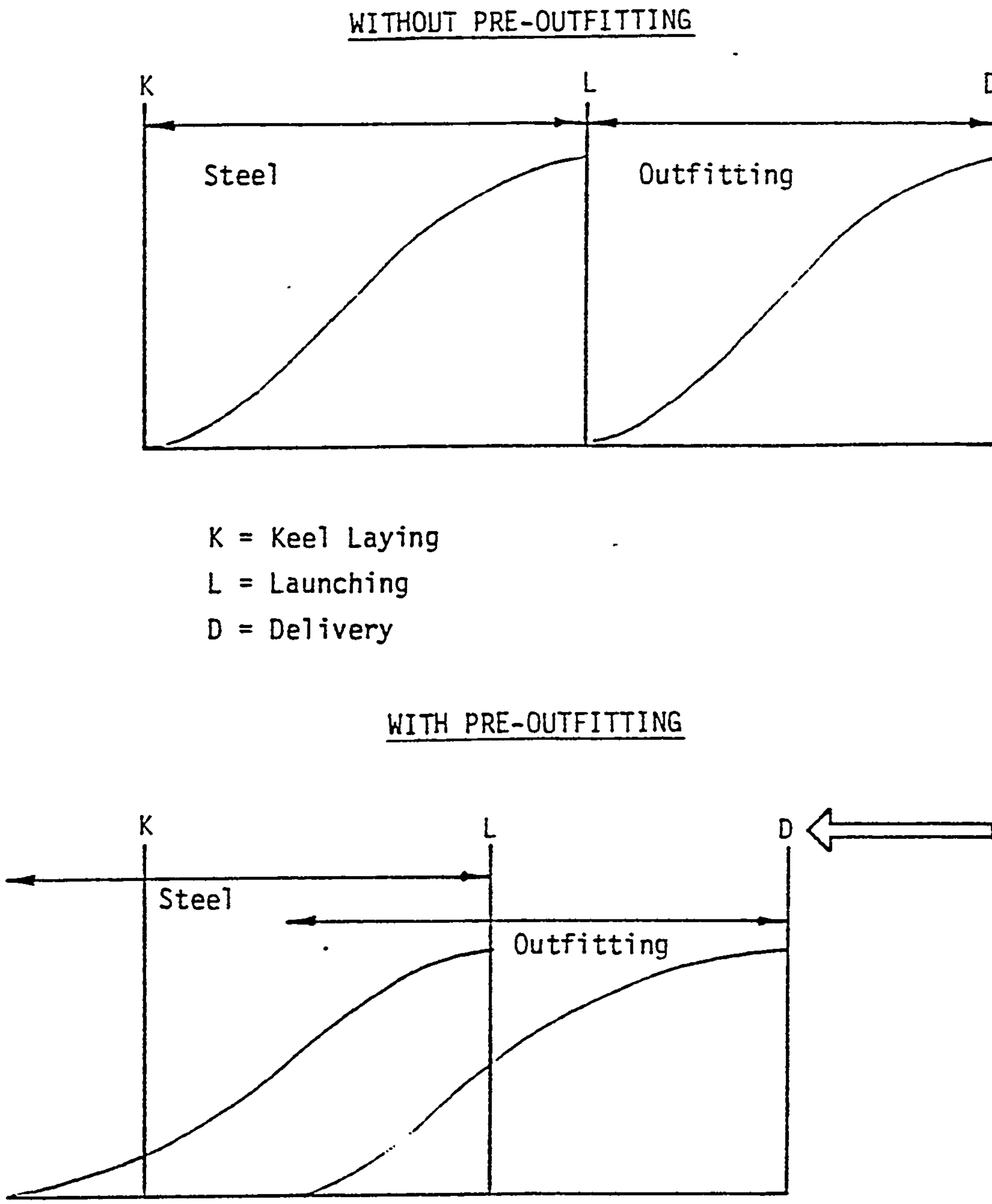
IHI adopted the concept of zone outfitting in order to shorten construction periods. The advantages of zone outfitting over conventional outfitting are identified in Figure 3-26. In particular, benefits were achieved significantly between keel laying and launch dates. Zone outfitting is an attempt to shorten the total construction period through an overlapping of steel and outfitting without interference between them. This concept is illustrated in Figure 3-27. The overlap of steel and outfitting resulted in over 50 per cent completion of total outfitting by launch date.

The zone outfitting approach released outfitting work from dependence on steel construction progress and from the ship's system arrangement. The zone approach permits and encourages most of the outfitting to be accomplished earlier and in shops or places other than erection sites. It is product-oriented in that it ignores systems during the construction phase and instead focuses on production of interim products. The benefits of this approach, in addition to a shorter construction period, include




ZONE OUTFITTING

FIGURE 3-26




Overlapping of steel and outfitting
enabled more than 50% completion
of total outfitting as of launching.

OVERLAP OF STEEL AND OUTFITTING

FIGURE 3-27

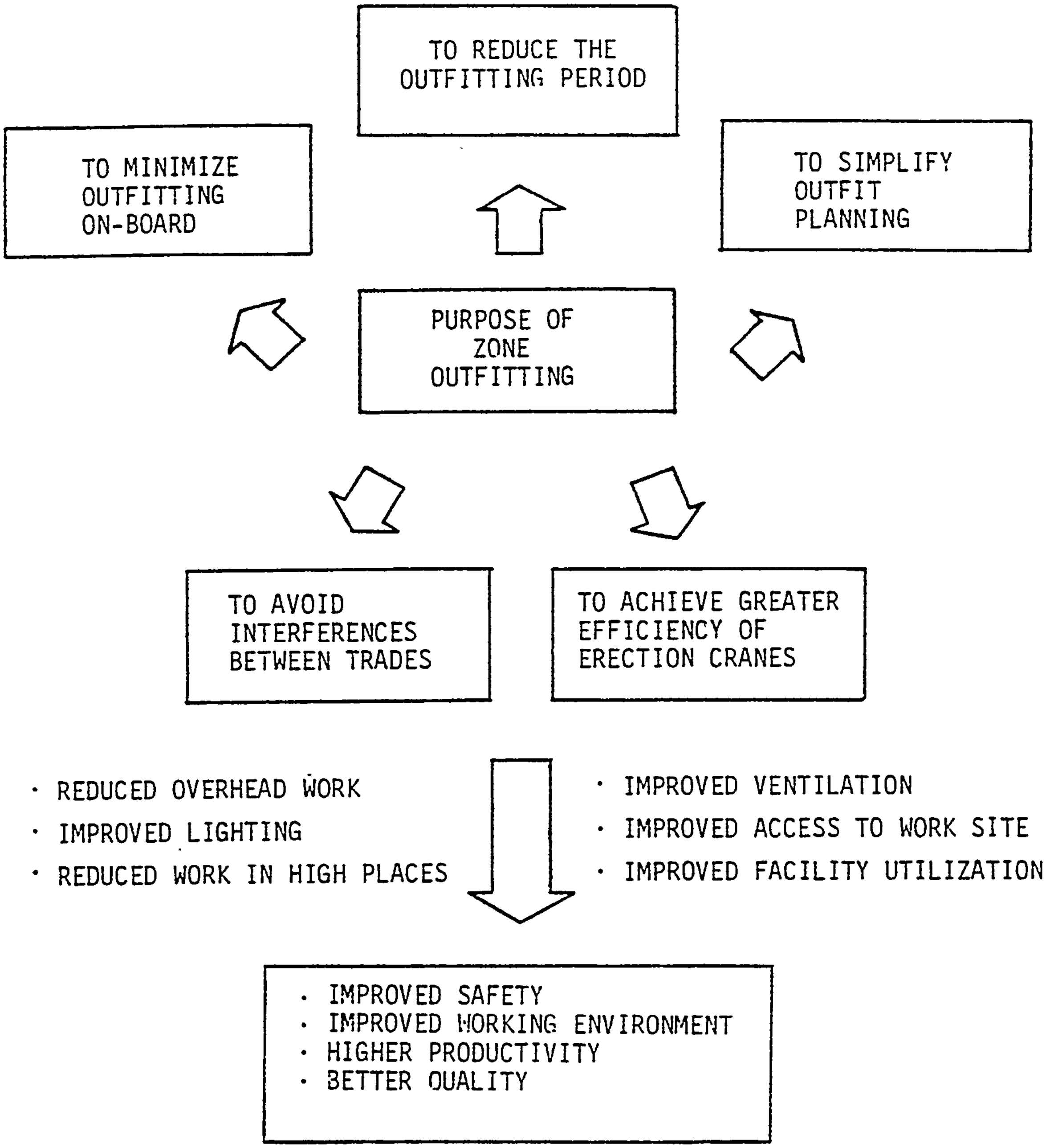
safer work, reduced cost, better quality and adherance to schedules. Figure 3-28 summarizes the goals and benefits of zone outfitting.

Zone outfitting features three basic stages: on-module, on-unit, and on-board. On-module and on-unit outfitting are generally referred to as "pre-outfitting".

Pre-outfitting generally can be classified into either on-module, or on-unit outfitting. On-module outfitting is the assembly of an interim product consisting of manufactured and purchased components. On-module outfitting is given the highest priority at IHT despite the impact it may have on steel construction progress or even hull design. For example, in construction of the engine room innerbottom tank top, the side shell and bulkhead are elevated six to ten feet to avoid interference between modules and the side shell web during side shell erection.

On-unit outfitting is the installation of outfit components onto a hull unit during its assembly and/or after its completion. It is the next best alternative to on-module outfitting. On-unit outfitting may be done on a hull assembly slab, or a unit may be moved to an area (inside or outside) that is designated for outfitting.

Although on-unit outfitting requires close coordination between steel, outfitting and painting, it provides much better working conditions, accessibility and utilization of equipment than on-board work. On-unit outfitting on the engine flat'units is especially beneficial due to the heavy concentration of material beneath the flats and the ability to apply downward installations on units that can be placed in an inverted position. IHI practices extensive application of on-unit outfitting on engine flat units.




**GOALS AND BENEFITS OF ZONE OUTFITTING**

**FIGURE 3-28**

As a result of high pre-outfitting, the on-board outfitting can be limited to the connection of modules and pre-outfitted units, final painting, tests and trials. Realistically, however, some installation of outfit components in a hull will remain for installation at erection sites or outfitting piers which cannot be productively incorporated into on-module or on-unit outfitting.

Incorporation of the pre-outfitting method results in fewer total manhours due to the work being performed under high-efficiency conditions. This is substantiated in Table T3-4 which shows a productivity comparison between pre-outfitting and on-board outfitting. The data was collected from the engine room outfitting of a bulk carrier built at the IHI-Aioi shipyard. In summary, this table portrays on-module outfitting as over seven times more efficient than on-board outfitting; on-unit outfitting three times as efficient; and total pre-outfitting four times faster. In this case, 77 per cent by weight of the outfitting in the engine room was pre-outfitted.

Palletization

The pallet concept is an indispensable system for effective zone outfitting. Literally, a pallet is a container in which materials are contained and transported to the work site for installation. Figure 3-29 shows the design of the type of pallets commonly used at IHI.

The word "pallet" at IHI refers more generally to a unit of work specified by zone, and a unit of materials identified by zone. It is a conceptual approach that allows information from the design, material and production departments to integrate so that each can have a common understanding of shipbuilding management and control.

Pursuing the merits of pre-outfitting inevitably leads to incorporation of palletizing methods. However, the palletizing concept can be

PALLET USED IN IHI

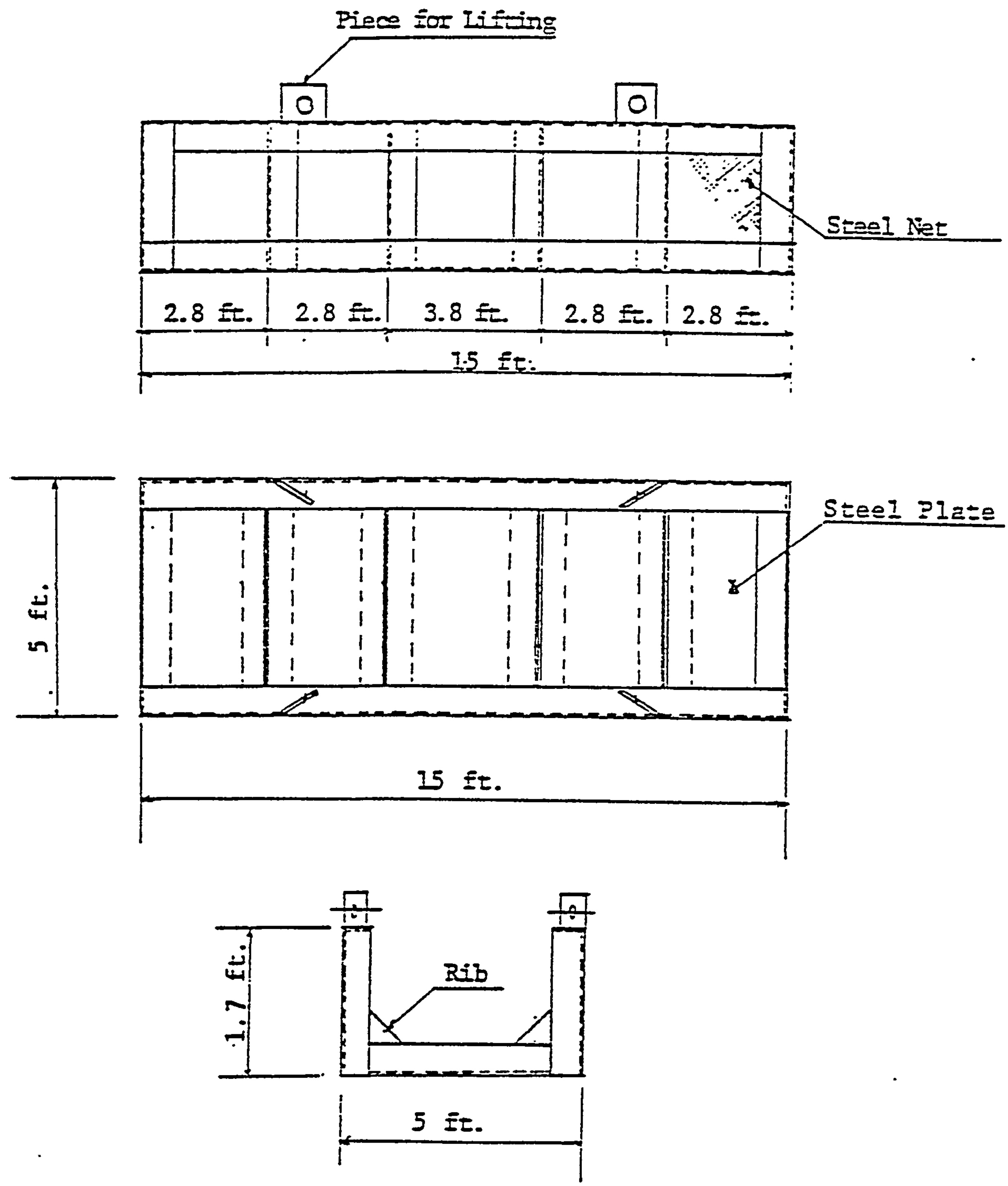



**FIGURE 3-29**

adopted independently of pre-outfitting development. In pre-outfitting, certain units are specified, such as for a compartment or zone of a ship, a group of fittings surrounding certain machinery, or a group of tubing arrangements. In palletizing, the regional unit can be further divided into regions from the viewpoint of job stages or job procedures. Thus, the palletizing concept may be executed with the primary intention of optimizing the job itself, whether it is at a pre-outfitting or an on-board stage.

It is a fundamental prerequisite that composite drawings and Material Lists for Fitting (MLF's) be prepared for full implementation of the palletizing concept. In order to load materials completely in a pallet, it is convenient to use the MLF as a check-list and to utilize it as a ticket for the materials being issued.

A common use of the pallet system is for the palletizing of pipe and piping components. Other material can also be palletized in conjunction with the composite drawing and the MLF systems, such as electrical supplies, joiner material, ductwork, steel outfittings, etc.

IHI recommended the complete-"pallet" concept to Levingston, as a means to improve productivity without a great amount of capital expenditure. Levingston has made a significant number of changes in its systems and procedures to incorporate this philosophy.

## WELDING METHODS

The welding process *receives* considerable attention at IHI as they regard ship construction *as* primarily a welding process, all other activities being essentially supporting. This is apparent in the construction methods specified at IHI, where units are turned or built in various positions, even upside-down, in order to accommodate the most efficient welding processes.

IHI avoids overhead welding, cramped positions for welding, manual welding methods and rework. The importance of welding at IHI is also demonstrated in their wide application of welding standards in the determination of assembly times for planning and scheduling purposes.

The welding methods in use at IHI-Aioi are listed in Table T3-5. A midship section showing typical application of automatic welding on a 70,000 DWT bulk carrier is shown on Figure 3-3Q. Following this sketch is a complementary chart describing automatic welding in modernized shipbuilding, Table T3-6 listing types of welding methods and applications of each type.

The types of welding methods employed at IHI are not significantly different from those used at Levingston. However, significant differences exist between the application of these methods; e.g., the amount of automatic welding, the dictation of construction methods by welding methods, and the adherence to the predetermined welding sequence. The methods employed at IHI and transferred to Levingston include vertical downward welding and gravity welding. Other methods studied jointly by IHI and Levingston include one-sided welding, pipe welding, welding sequence and welding applications at each construction stage.

Vertical downward welding is a process which utilizes a specially designed, low-hydrogen type electrode. This welding method is a proven high-efficiency vertical welding method. A comparison between vertical upward and vertical downward welding indicates the downward method is two

| Kind of Welding Method | Division | Popular Name | Stage | Part of Mainly Application |
|---|---|---|---|---|
| $CO_2$ arc welding | Each side semi-automatic | | All | Butt & Fillet joint of flat position |
| | One side semi-automatic | | Assembly Erection | Butt & Fillet joint of flat position |
| | One side automatic | DTM process | Erection | Flat & Vertical butt joint of internal member |
| Submerged arc welding | Each side one pass | | Sub-assembly | Plate joint of panel |
| | Combined with one side $CO_2$ arc welding | | Assembly Erection | Plate joint of panel |
| | Combined with manual arc welding | | Assembly | Butt joint of curved shell |
| | One side by apparatus | FCB process | Assembly | Plate joint of panel |
| | One side with handy backing material | KATAFLUX or FAB | Assembly Erection | Butt joint of curved shell Block joint |
| | Fillet | MISA | Sub-Assembly | Fillet joint of panel to internal member |
| Electro-Gas & Electro-Slag welding | Automatic Electro-Gas | Elegas | Erection | Vertical butt joint of S. shell & Bulkhead |
| | Simplified Electro-Gas | SEG | Erection | Vertical butt joint at short length |
| | Consumable nozzle Electro-Slag welding | CES | Erection | Vertical butt joint of Longitudinal stiffener member |
| Horizontal Automatic welding | One side with $CO_2$ arc welding | M3-ZA | Erection | Horizontal butt joint of Side shell |
| Non-Gas arc welding | Semi-automatic | Open arc | Erection | Horizontal fillet joint |
| | Automatic | Open arc | Erection | Horizontal fillet joint between T. Top & Hopper |

-TABLE T3-5

IHI WELDING METHODS

## TYPICAL APPLICATION OF AUTOMATIC WELDING IN BULK CARRIER (70,000 DWT)

1. ASSY. SEAM JOINT
   F.C.B.
3. DECK SEAM, TANK TOP SEAM
   AND BUTT

   F.A.B. OR KATAFLUX
4. ASSY. HORIZONTAL FILLET WELD
   LINE WELDER
7. SIDE SHELL BUTT
   P. ELE - GAS
14. LONG'L BHD BUTT
    ELE - GAS
15. SIDE SHELL SEAM
    M3-Z
16. BOTTOM SHELL BEAM AND BUTT
    OSCON-OB
17. DECK LONG'L BUTT
    C.E.S.

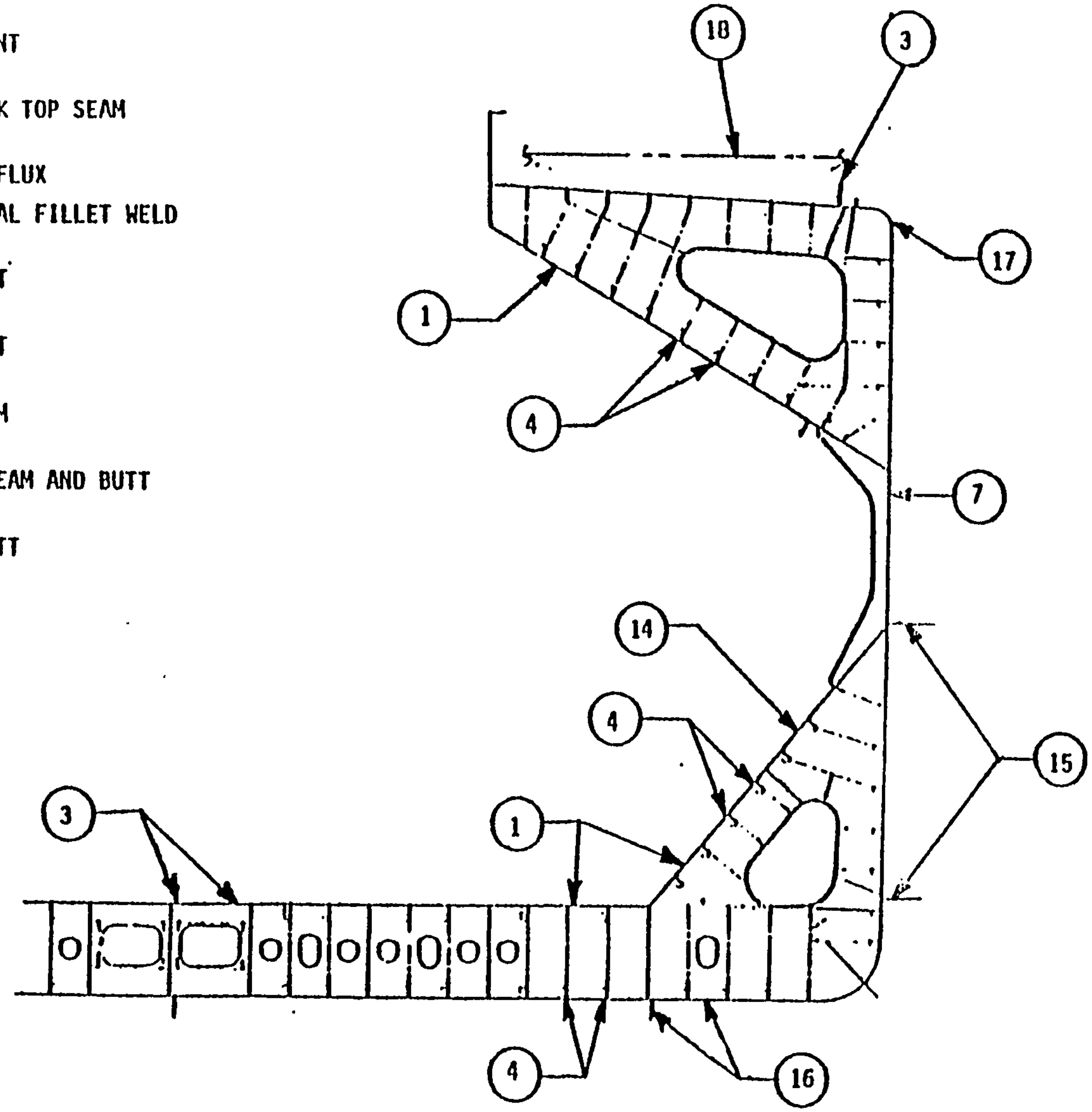



FIGURE 3-30

## TABLE T3-6

### AUTOMATIC WELDING IN MODERNIZED SHIPBUILDING

| ITEM | NO. | WELDING METHOD | APPLICATION |
|---|---|---|---|
| One-Sided Plate Welding | 1 | Flux copper backing one-sided submerged arc welding (F.C.B. Process) | Panel block joint on assembly stage |
| | 2 | RF-1 Flux one-sided submerged arc welding (RF Process) | Panel block joint on assembly stage |
| | 3 | Flux asbestos backing one-sided submerged arc welding (F.A.B. Process) | Curved part panel block joint on assembly stage bottom shell plate seam & deck plate seam joint on erection stage |
| Frame Welding on Assembly Stage | 4 | Twin tandem horizontal fillet welding (T.T.F. Process or line welder) | Horizontal fillet of longitudinal members on panel plate |
| | 5 | Fillet bead in the vertical position with gasless arc welding (SA-unit) | Vertical fillet welding between the transverse and longitudinal members |
| | 6 | Portable sumberged arc fillet welding (SUBSTAR-1) | Horizontal fillet welding of eggbox & innerstructure |
| Welding on Work Unit (Erection Stage) | 7 | Electro gas arc welding with press roller | Butt joint on transverse bulkhead & bottom transverse |
| | 8 | Powder plug arc welding (P.P.A. Process) & Contact bar submerged arc welding (CBS Process) | Butt joint on longitudinal of side shell & longitudinal bulkhead |
| | 9 | One-sided electro gas arc welding (S.E.G. Arc-S Process) | Butt joint on deck transverse web plate |

| ITEM | NO. | WELDING METHOD | APPLICATION |
|---|---|---|---|
| Welding on Work Unit (Erection Stage) | 10 | Consumable nozzle electro slag welding (C.E.S. Process) | Web plate of cross tie |
| | 11 | C.E.S. and F.A.B. process by same welding & wire (KOB-FAB Process) | Horizontal Girder |
| | 12 | Semi-automatic $CO_2$ welder | Face plate of cross tie |
| | 13 | | Web plate of side longitudianl face plate of cross tie |
| Others on Erection Stage | 14 | Electro gas arc welding | Butt joint on side shell & longitudinal bulkhead |
| | 15 | | Seam joint on side shell plate |
| | 16 | | Seam & butt joint on bottom shell plate |
| | 17 | | Butt joint on round gunnel part |
| | 18 | Consumable nozzle electro slag welding (C.E.S. Process) | Butt joint on deck longitudinal, lower longitudinal bulkhead & engine girder |
| | 19 | Twin electrode type consumable nozzle electro slag welding (KOB-BL Process) | Butt joint on bottom longitudinal |

to four times faster in arc time than vertical upward. This method is applicable to welding at the sub-assembly, assembly and erection stages.

One-Sided Welding

IHI utilizes the one-sided welding method in various applications of the assembly and erection stages. The processes utilized include F.C.B. (Flux Core Backing), F.A.B. (Flux Asbestos Backing), R.F. (RF-l Flux), and CO2 one-sided welding.

The one-sided welding method utilizes backing strips that function similarly in principle but differently in design which allow the welding bead to join both plates with the application of welding on one side only. One-sided welding offers the obvious advantages of elimination of welding on the reverse side of the plates, elimination of plate turnover and handling and less overhead space required for this turnover. Fewer cranes and more conveyors can thus be used for more efficient and productive work.

Other Auto/Semi-Auto Welding Methods

The submerged-arc welding method is a highly efficient welding method with large heat input and is most widely applied to a straight welding line. This method is most commonly utilized to weld flat butt joints at the sub-assembly and assembly stages.

Co2 gas semi-automatic arc welding is performed at IHI using standard CO2 welding equipment. CO2 arc welding methods are utilized in one-sided and two-sided welding applications.

Electro-gas welding is a form of CO2 gas arc welding used on the vertical butt joints of side shells and bulkheads. The welding equipment is lifted by a chain block hanging on top of the butt joint. The welding operator ascends the side of the vessel in an automatically driven gondola, progressing at the speed of his welding. The weld metal is applied in the joint using water cooled sliding copper shoes.

Gravity welding is a semi-automatic welding method which utilizes natural gravity in the welding process. It is primarily applicable to horizontal fillet welds in the assembly or sub-assembly stages.

The gravity welding unit is a simple structure designed to hold the electrode at the proper drag angle and proper electrode angle-to-joint posture.

The amount of automatic welding applied to hull steel construction on the different types of ships built at IHI is specified in Table T3-7. The ratio of automatic welding to manual welding for the F-32 ships is given as follows:

Sub-assembly...............66.0%

Assembly...................42.7%

Erection...................11.9%

Total Hull ................44.4%

IHI believes in a pre-determined welding sequence that is strictly adhered to in the construction process.. The welding sequence proposed by IHI for the bulkers at assembly and erection is illustrated in Figures 3-31 and 3-32.

Pipe welding equipment available at the IHI-Aioi shipyard includes:

| Machine | Capacity | Quantity |
|---|---|---|
| NC 4-point welder | 2-1/2" | 1 |
| NC 2-point welder | 2-1/2" | 1 |
| $CO_2$ Gas shield arc welder | 300A | 28 |
| $CO_2$ Gas shield arc welder | 500A | 5 |

## TABLE T3-7

## AUTO-WELDING RATIO IN IHI'S AIOI SHIPYARD (EXCLUDING SUBCONTRACTING)

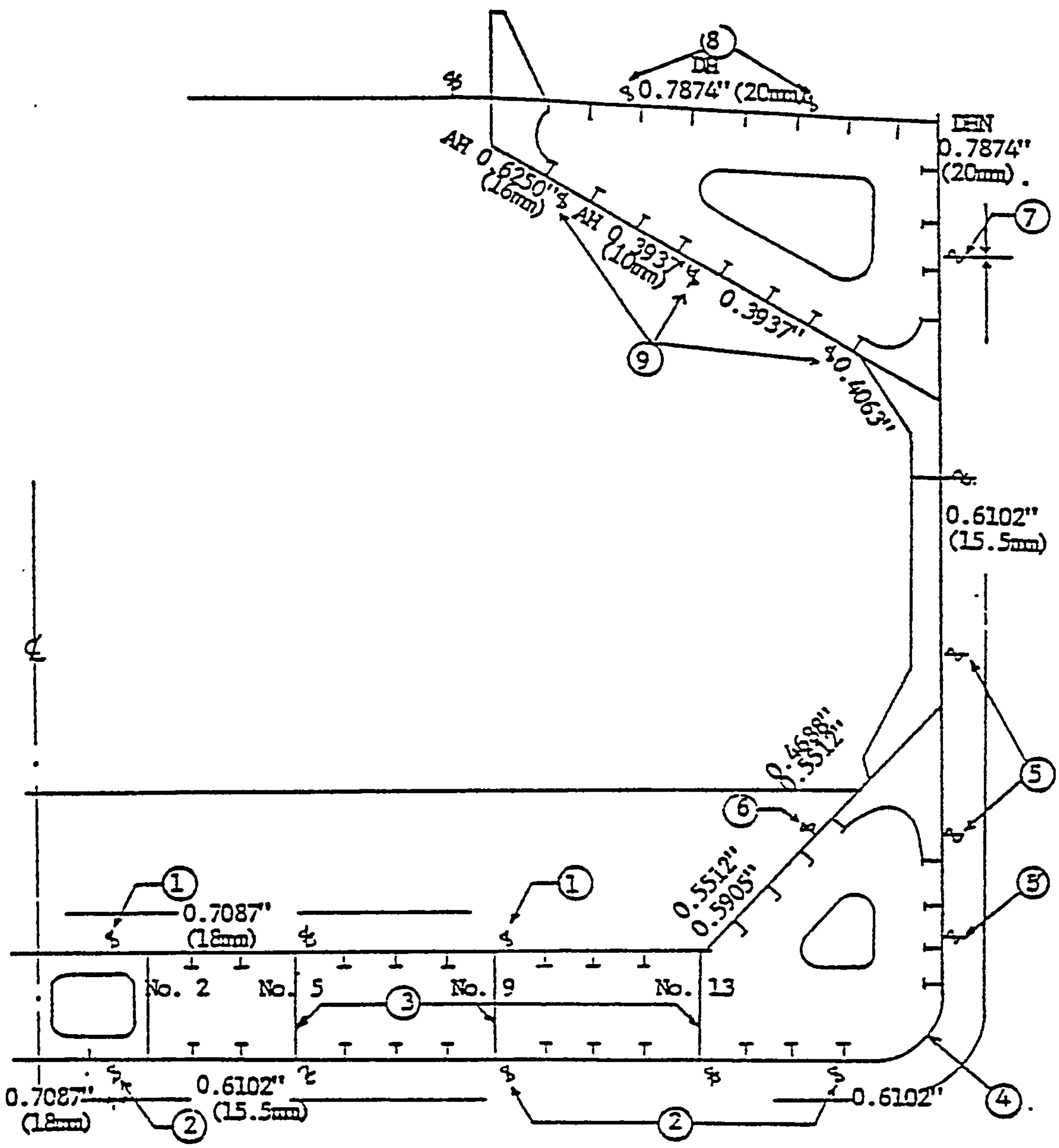
| Type of Ship | Hull Steel | | No. of Units | Sub-Assembly | | | | Assembly | | | | Erection | | | | Total Hull Steel | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | H.T. | | Auto-Welding | Manual Welding | Sub Total | Ratio | Ratio | Manual Welding | Sub Total | Ratio | Auto Welding | Manual Welding | Sub Total | Ratio | Auto Welding | Manual Welding | Total | Ratio |
| | ) | (T) | | (H) | (H) | (H) | (%) | (H) | (H) | (H) | (%) | (H) | (H) | (H) | (%) | (H) | (H) | (H) | (%) |
| Future | | | | | | (22.5) | | 4,223 | 90,404 | (66.8) | 4.5 | | | (10.7) | | 26,773 | 114,867 | | 18.9 |
| - 32 | 5,432 | 472.3 | 114 | | | 31,923 | | | | 94,627 | | 1,800 | 13,290 | 15,090 | 11.9 | | | 141,640 | |
| | | | | 20,750 | 11,173 | | 65 | (G) 36,161 | 54,243 | | 42.7 | | | | | 62,934 | 78,706 | | 44.4 |
| Friend | 4,138 | | 66 | | | (24.7) | | 3,743 | 67,081 | (65.3) | 5.3 | | | (10.0) | | 22,653 | 85,706 | | 20.9 |
| Ship | | | | | | 26,715 | | | | 70,824 | | 1,545 | 9,275 | 10,820 | 14.3 | | | 108,359 | |
| | | | | 17,365 | 9,350 | | 65 | (G) 26,832 | 40,249 | | 43.2 | | | | | 49,485 | 58,874 | | 45.7 |
| Freedom | 2,692 | | 72 | | | (25.3) | | 2,411 | 57,108 | (64.7) | 4.0 | | | (10.0) | | 18,475 | 73,568 | | 20.0 |
| | | | | | | 23,294 | | | | 59,519 | | 923 | 8,307 | 9,230 | 10.0 | | | 92,0[illegible] | |
| | | | | 15,14[illegible] | 8,153 | | 65 | (G) 22,843 | 34,265 | | 42.4 | | | | | 41,318 | 50,725 | | 44.9 |
| Freedom | 2,840 | | 54 | | | (27.1) | | 2,393 | 51,881 | (64.7) | 4.4 | | | (8.2) | | 17,851 | 66,039 | | 21.3 |
| - II | | | | | | 22,720 | | | | 54,274 | | 690 | 6,200 | 6,896 | 10.0 | | | 83,30[illegible] | |
| | | | | 14,768 | 7,952 | | 65 | (G) 20,752 | 31,129 | | 38.2 | | | | | 38,603 | 45,287 | | 46.0 |
| 60,000 | 8,067 | 1,753.2 | 153 | | | (28.6) | | 7,674 | 11,243 | (61.7) | 6.5 | | | (9.8) | | 38,110 | 154,761 | | 19.8 |
| Tanker | | | | | | 55,111 | | | | 118,917 | | 2,881 | 15,963 | 18,844 | 15.3 | | | 192,87[illegible] | |
| | | | | 27,555 | 27,555 | | 50 | (G) 44,497 | 66,746 | | 43.9 | | | | | 82,607 | 110,264 | | 42.8 |
| Container | 10,926 | | 223 | | | (28.0) | | 4,938 | 28,484 | (59.0) | 3.7 | | | (13.0) | | 31,120 | 195,073 | | 13.8 |
| (1240) | | | | | | 63,271 | | | | 133,422 | | 874 | 28,620 | 29,500 | 3.0 | | | 226,19[illegible] | |
| | | | | 25,308 | 37,963 | | 40 | (G) 38,545 | 89,939 | | 32.6 | | | | | 69,665 | 156,528 | | 30.8 |
| | | | | | | 26% | | | | 64% | | | | 10% | | | | | 19.1 |
| | | | | | | | | | | | | | | | | | | | 42.4 |

NOTE: $\text{RATIO} = \dfrac{\text{Welding Length of Auto, Semi-Auto and Gravity}}{\text{Total Welding Length}} \times 100$

(1) Sub-Assembly: including gravity welding

(2) Assembly : upper not including gravity welding. lower including gravity welding. (G) : Welding Length of Gravity Welding

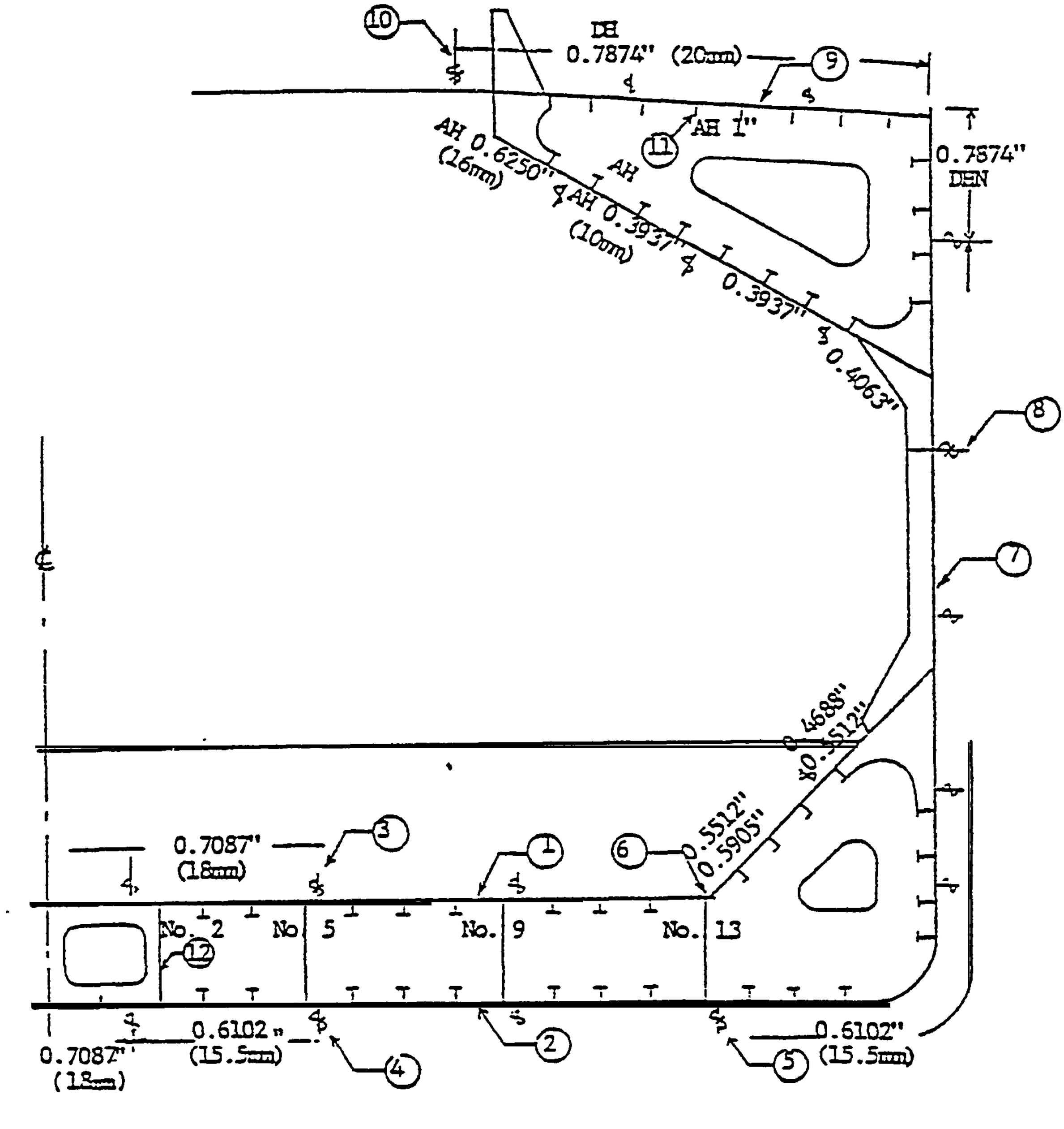
WELD SEQUENCE-ASSEMBLY STAGE




MIDSHIP SECTION

FIGURE 3-31

## WELD SEQUENCE ERECTION STAGE




MIDSHIP SECTION

FIGURE 3-32

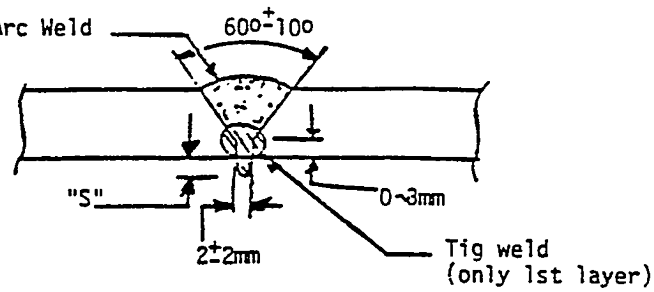
| Machine | Capacity | Quantity |
|---|---|---|
| DC Tungsten inert-gas welder | 200A | 4 |
| DC Tungsten inert-gas welder | 500A | 1 |
| AC Shield metal arc welder | 200A | 7 |
| AC Shield metal arc welder | 300A | 4 |
| AC Shield metal arc welder | 400A | 6 |
| AC Shield metal arc welder | 500A | 10 |

TIG welding is principally applied to pipe finished in accordance with Grades A and B and mostly arc welding to pipe finished to Grade C. The butt welding method for TIG welding is illustrated in Figure 3-33. with a chart of maximum allowable values (metric) for height of the inside welding bead "S". Figure 3-34 provides illustration of the butt welding method of arc welding and a table of metric gap values.

## JIGS AND FIXTURES

IHI has developed innumerable jigs and fixtures for use throughout the shipyard. Levingston has adopted some of the major jigs, such as the adjustable pin jig system for curved unit assembly, as well as some of the smaller jigs. The jigs and fixtures used at IHI are too numerous to list. Naturally, a number of these are designed to complement the IHI facilities and methods of operation and may not apply elsewhere.

Some of the jigs currently in use have been illustrated by sketches, including some made by Levingston with minor modification. A composite of these sketches of jigs and fixtures is provided on the following pages as being representation of typical jigs used at IHI.




Dimension ; mm

| Pipe grade | Nominal dia | "S" (Max) | |
|---|---|---|---|
| A GRADE | All dia. | All around | 2 |
| | 15ᴬ 25ᴬ | Partial | 2 |
| | 40ᴬ above | Partial | 4 |
| B GRADE | 15ᴬ, 25ᴬ | All around | 3 |
| | 40ᴬ above | All around | 3 |
| | 15ᴬ 25ᴬ | Partial | 3 |
| | 40ᴬ ~ 65ᴬ | Partial | 4 |
| | 80ᴬ above | Partial | 5 |

BUTT WELDING METHOD - TIG WELDING

FIGURE 3-33

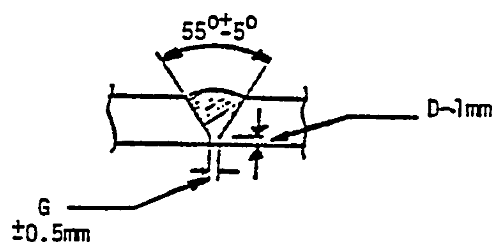



Table of Gap. (unit: mm)

| Thick. \ Nom. Dia. | 15 | 20 | 25 | 40 | 50 | 65 | 80 | 100 | 125 | 150 | 200 | 250 | 300 | 350 & above |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SGP | | | | | | | | | | | | | | |
| Sch 40 | | G = 1.0 | | | | | G = 2.0 | | | | | | | |
| Sch 80 | | | | | | | | | | G = 3.0 | | | | |
| Sch 120 | | | | | | | | | | | | | | |

BUTT WELDING METHOD - ARC WELDING

FIGURE 3-34

| NUMBER | COMPANY | DESCRIPTION | USE |
|---|---|---|---|
| Fig. 3-35 | IHI | Plate Positioner | Positions plate on the conveyor leading to the shot blast facility. |
| Fig. 3-36 | IHI | Flat Bar Setting Jig | Positions flat bar eliminating tack welding. |
| Fig. 3-37 | LSCo | Tee Support | Supports T-bar at the setting stage on panel line. |
| Fig. 3-38 | LSCo | Alignment Jig | Aligns face plate to eliminate a welded piece. |
| Fig. 3-39 | IHI | Parallel Check Device | Checks plates for parallel to Planer Rail. |
| Fig. 3-40 | IHI | Gas Cutter Stopper | Self-stopping mechanism for gas cutting machine. |
| Fig. 3-41 | IHI | Angle Lifting Hook | Clamp for lifting angles. |
| Fig. 3-42 | IHI | Tee Lifting Hook | Clamp for lifting T-bar. |
| Fig. 3-43 | IHI | Unit Lifting Hook | Hook to lift assembled units by plating through existing holes. |
| Fig. 3-44 | IHI | Hole Cutter-Shell Plate | Cuts circular holes in curved shell plate using gas cutter. |
| Fig. 3-45 | IHI | Hole Cutter - Suction Box | Cuts circular holes in Sea Water Suction Box using gas cutter. |
| Fig. 3-46 | IHI | Roller with Guides | Portable roller bender used with a bending guide mounted on the upper roller. |
| Fig. 3-47 | IHI | Reamer Jig | Reamer bolt squeezing jig used to eliminate awkward work in narrow spaces. |
| Fig. 3-48 | IHI | Bolt Alignment Jig | Tapered alignment jig used for a reamer bolt on an intermediate shaft coupling. |

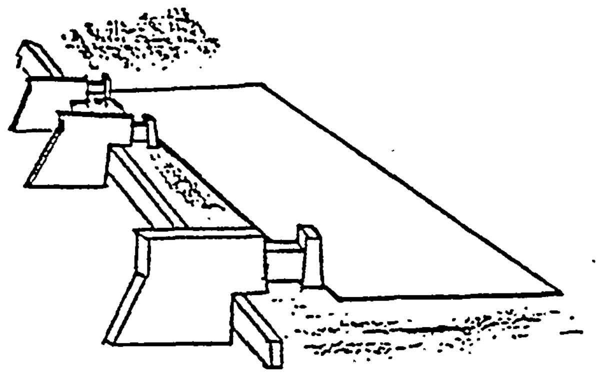


FIGURE 3-35

IHI: Plate Positioner

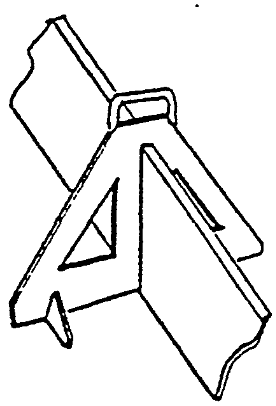


FIGURE 3-36

IHI: Flat Bar Setting Jig

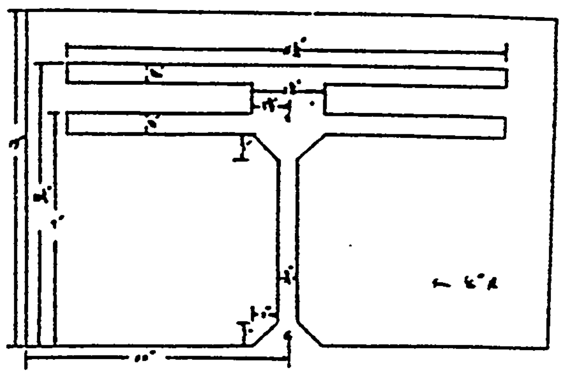


FIGURE 3-37

LSCo: Tee Support

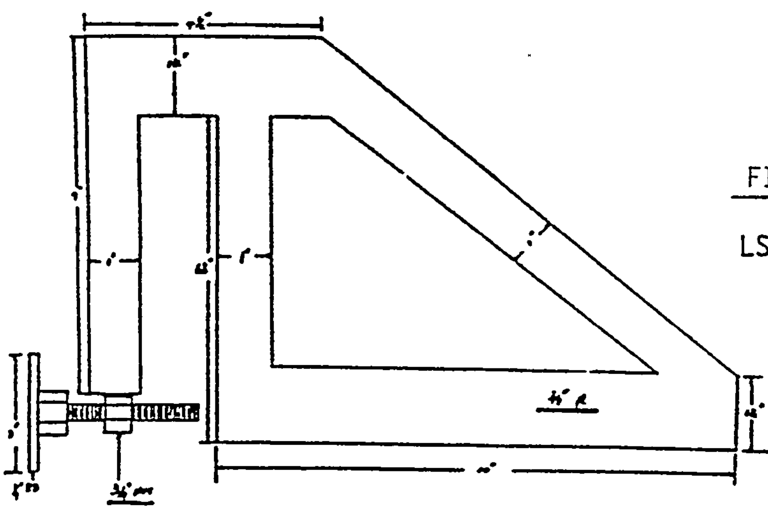


FIGURE 3-38

LSCo: Alignment Jig

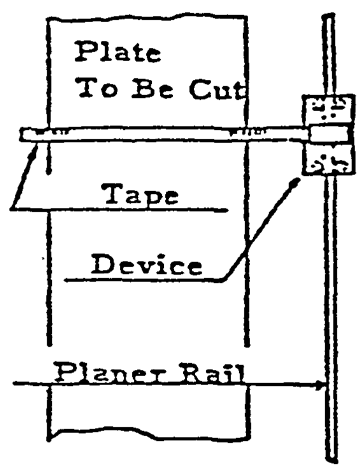
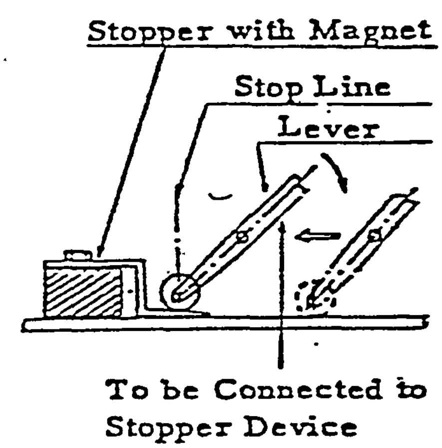



FIGURE 3-39

IHI: Parallel Check Device

FIGURE 3-40

IHI: Gas Cutter Stopper



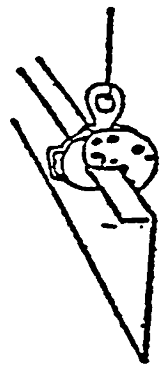


FIGURE 3-41

IHI: Angle Lifting Hook

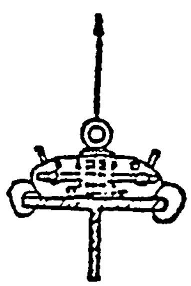


FIGURE 3-42

IHI: Tee Lifting Hook

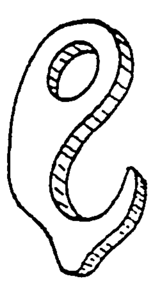


FIGURE 3-43

IHI: Unit Lifting Hook

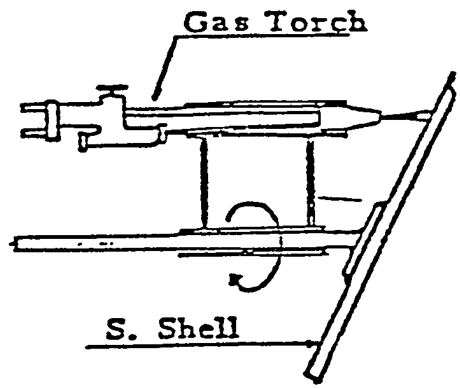



FIGURE 3-44

IHI: Hole Cutter - Shell Plate

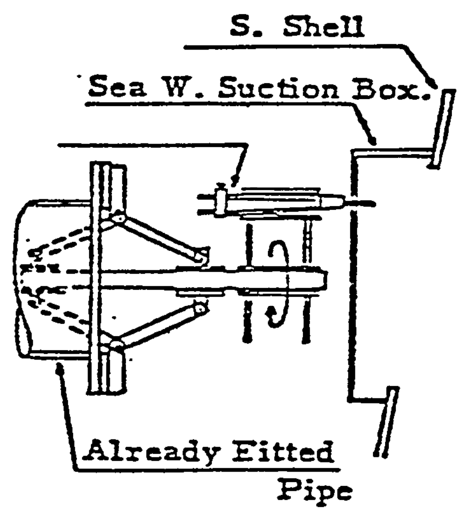



FIGURE 3-45

IHI: Hole Cutter - Suction Box

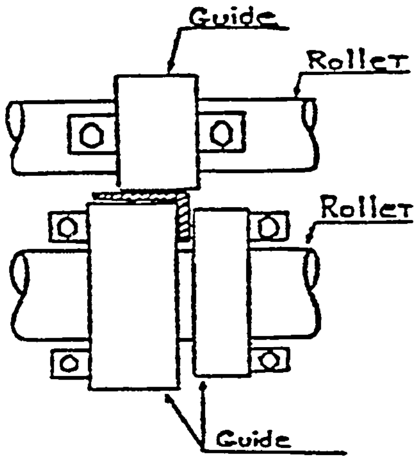



FIGURE 3-46

IHI: Roller with Guides

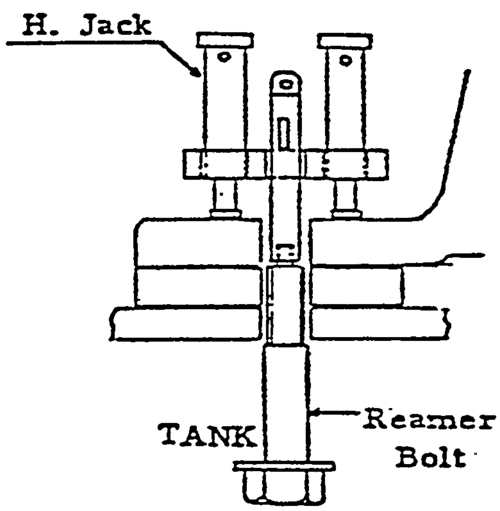



FIGURE 3-47

IHI: Reamer Jig

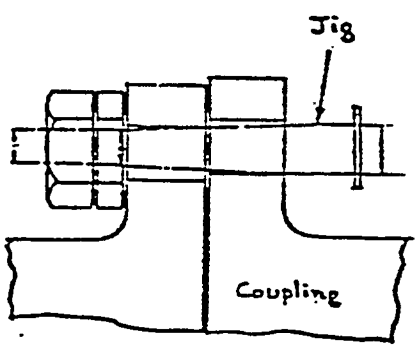



FIGURE 3-48

IHI: Bolt Alignment Jig

## FACILITY IMPROVEMENT PLAN

The Levingston Shipbuilding Company Facility Capacity and Capability Study was conducted in July, 1979, under Sub-task 4.1 of the TTP. This study served as a baseline in the evaluation of Levingston facilities for future improvements.

### FACILITY INFORMATION - LSCo AND IHI

The Levingston facility at Orange began building steel vessels in 1933. Since then over 700 steel vessels of all types have been constructed. This includes 163 vessels for the offshore industry, 167 vessels for the U. S. Government, and 372 commercial vessels.

The bulk carriers presently under construction are a modified design of IHI's Future-32 vessel. The largest ships ever built at Levingston, they represent Levingston's first major commercial vessels. Differences in facilities, lifting capabilities, methods and other factors result in different construction techniques between the LSCo and IHI shipyards.

The Aioi shipyard at IHI is considered to be comparable to a medium-sized American shipyard. A comparison of IHI and Levingston facilities was undertaken and some of the results are shown below:

Facilities at the IHI-Aioi shipyard include the following:

Building Dock #1:
180,000 DWT Capacity -
Crane Capacity: 2 x 200 ton
2 x 80 ton

Building Berth #3:
164,000 DWT Capacity
Crane Capacity: 2 x 120 ton
2 x 80 ton

Shipbuilding Capacity: 8,000 tons per month or
12 F-32 ships per year

Ground Area: 635,034 m2 (6,835,673 ft2)

Building Area: 103,332 m2 (1,112,293 ft2)

LSCo MARKET PROJECTIONS

At the time Levingston negotiated its five-ship bulker contract in 1978, the future market for the company's business was projected as follows:

45 per cent Bulkers or Tankers

30 per cent Jack-up Rigs

25 per cent Ship Repair

Since that time, demand for jack-up rigs has increased significantly, and strategy was revised in 1980 to reflect this shift in market conditions, to the following breakdown:

30 per cent Bulkers or Tankers

45 per cent Jack-up Rigs

25 per cent Ship Repair

Current business at Levingston includes five jack-up rigs (one launched, one under construction three not yet started), and the bulker contracts (one launched, two under construction, and the remaining two optional vessels in the original contract having been cancelled). Negotiations are underway for at least two more jack-up orders and two bulk-container ships.

The comparison between IHI and Levingston shipyards illustrates the differences in their markets and facilities. The approach taken in the Levingston Facility Study was to determine those improvements suggested by the IHI consultants that would benefit Levingston. With the explanation of the methodology of this facility study, an analysis of the Facility Study is now appropriate.

The IHI facilities were analyzed for comparison with LSCo facilities considering the throughput rates of each area. From a facility standpoint, IHI is highly productive due to a large ratio of enclosed areas, automated equipment, efficient layouts, and high equipment utilization, among other factors.

As a result of analysis of IHI facilities, a review of IHI recommendations, and projected requirements for LSCo throughput rates, a number of suggested improvements were made in the Sub-task 4.1 Final Report. These recommendations, and the actions taken up to the present time, can be summarized as follows:

1) Install an N/C Drafting Machine (agreed to in principle).

2) Install an N/C Burning Machine with plasma cutting torches (completed).

3) Purchase a 1:l Optical Tracing Machine (completed).

4) Establish a Flame Bending Area, with work tables (completed).

5) Install a Panel Line operation (completed).

6) Install curved unit assembly jigs, or "pin jigs" (partially adopted).

7) Increase the amount of Assembly Areas (area increased by 40,000 ft2).

8) Build scaffolding for repeated use in bulker construction (some specifically designed scaffolding was used, but in other cases universal-type scaffold was rented).

9) Greater use of automatic welding equipment (LSCo has implemented one-sided welding in the Panel Line and this program is being expanded to Assembly Areas. Also, the use of vertical downhand welding rods was implemented).

10) Build new pipe shop (agreed to in principle).

11) Install automatic pipe bending machine (bought and installed 3" capacity machine).

12) Build pipe pallets and arrange storage for fabricated pipe in pallets (30 pallets built and storage area allocated).

Naturally, these improvements are considered to be of greatest need and', as described above, many have already been implemented. There are a number of other desirable improvements which would be beneficial to shipyard efficiency and productivity. These are reviewed below for each area with the thought in mind that some improvements will be as much as five years away. Those improvements affecting the bulker program, in turn relating more directly to TTP items, are emphasized.

## REVIEW OF AREAS FOR IMPROVEMENT

Table T3-8 lists desirable improvements throughout the shipyard which have not already been implemented. Each improvement has been categorized as being of high, medium or low priority, as determined by its relative significance compared to other needed improvements. These terms are loosely defined as follows:

> High Priority - Immediate benefit to be gained, in an area with relatively significant impact to other shipyard activity.
>
> Medium Priority - Substantial benefit foreseen, in a less significant area.
>
> Low Priority - No particular urgency, area not presently ready for improvement to achieve maximum benefits, or the area has less effect on operations as a whole.

Those improvements designated as high priority show up in the first or second year of the long range plan. The medium priority improvements are spread through the second to fourth year, while the low priority items are planned for the fourth or fifth year.

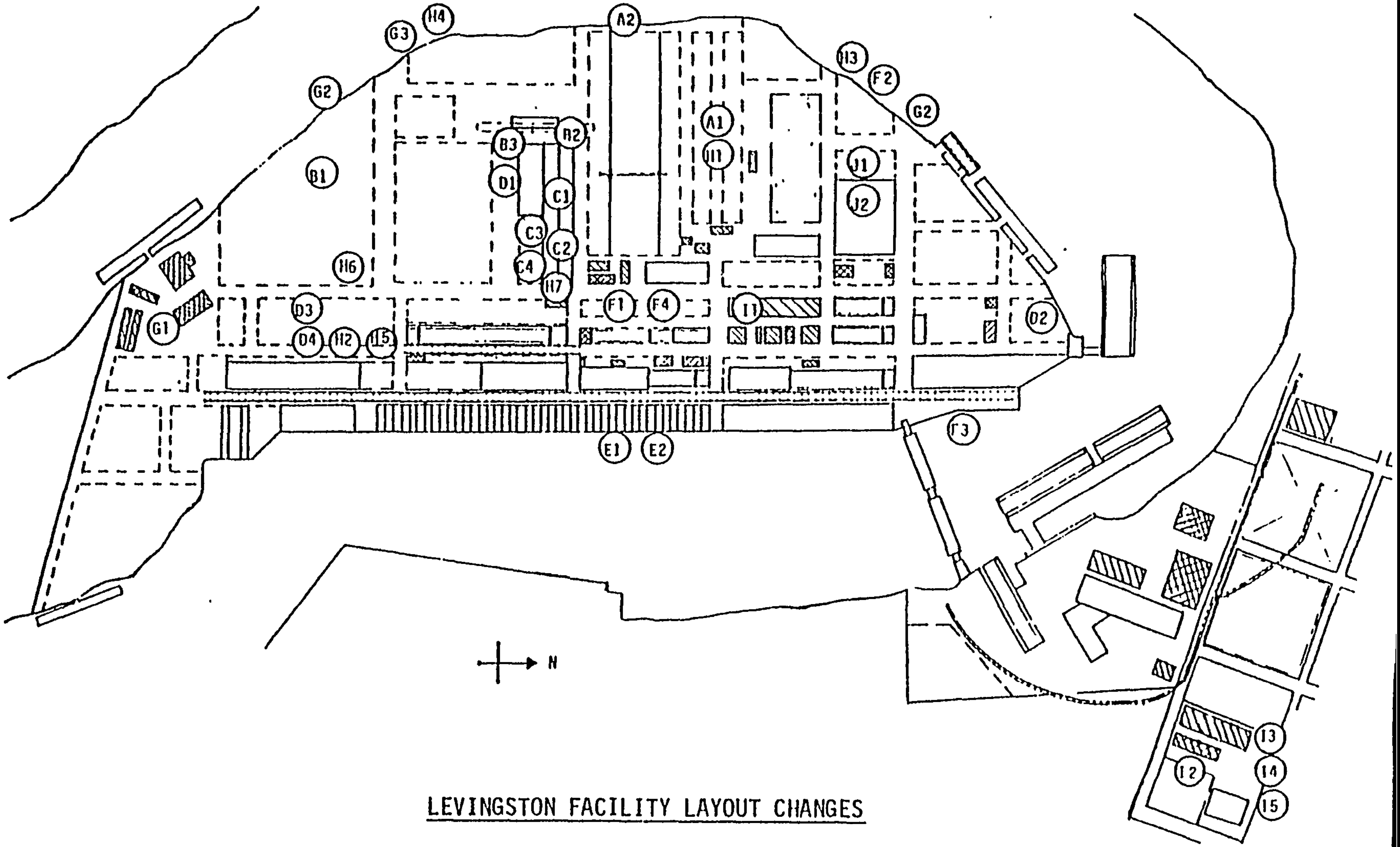
Figure 3-49is a layout of Levingston's facilities marked with the codings described on Table T3-8 to denote the location of improvements planned for the Levingston facility. Table T3-8 also specifies the main reason for each improvement in explanation of the benefits it would provide to the shipyard.

## TABLE T3-8

## PROPOSED IMPROVEMENTS

| AREA | IMPROVEMENT | REASON FOR CHANGE | PRIORITY | COST* | CODE |
|---|---|---|---|---|---|
| A. STEEL STORAGE | 1. CRANE TO HANDLE STRUCTURAL STEEL | MORE EFFICIENT UNLOADING & HANDLING | MEDIUM | 50 - 200 | A1 |
| | 2. EXTENSION OF MATERIAL HANDLING CRANE TO RIVER BANK | ALLOWS UNLOADING FROM BARGES | MEDIUM | 10 - 50 | A2 |
| B. STEEL PREP-ARATION | 1. INSTALL ENCLOSED ABRASIVE BLAST-ING FACILITY | POLLUTION CONTROL, ATMOSPHERIC CONTROL | MEDIUM | 500+ | B1 |
| | 2. INSTALL VERTICAL PLATE STORAGE RACKS | MORE EFFICIENT HANDLING & STORAGE | MEDIUM | 10 - 50 | B2 |
| | 3. REPLACE VERTICAL SHOT BLAST WITH HORIZONTAL TYPE | BETTER HANDLING OF MATERIALS | LOW | 500+ | B3 |
| C. FABRICA-TION SHOPS | 1. ADD CAB-OPERATED CRANE IN SHOP 5 | ADDED LIFTING CAPACITY | LOW | 50 - 200 | C1 |
| | 2. ADD 3000 TON VERTICAL PRESS | ADDED BENDING CAPACITY & VERSATILITY | HIGH | 500+ | C2 |
| | 3. EXTEND SHOP 6 | ORGANIZED MATERIAL FLOW; WEATHER PROTECTION | HIGH | 50 - 200 | C3 |
| | 4. ADD 10 TON CRANE - SHOP 6 EXTENSION | ADDED LIFTING CAPACITY | MEDIUM | 50 - 200 | C4 |
| D. ASSEMBLY AREAS | 1. BUILD NEW SHOP 7 FOR SUB-ASSEMBLIES | ORGANIZED MATERIAL FLOW: WEATHER PROTECTION | LOW | 500+ | D1 |
| | 2. DECK HOUSE ASSEMBLY AREA | ADDITIONAL SPACE & CRANE ACCESS | LOW | 50 - 200 | D2 |
| | 3. EXPAND SLAB AREAS & BUFFER STORAGE | INCREASED ASSEMBLY & STORAGE CAPACITY | MEDIUM | 200 - 500 | D3 |
| | 4. EXTEND GANTRY RAILS (2ND ST.) | TO SERVICE EXPANDED ASSEMBLY AREAS | HIGH | 50 - 200 | D4 |
| E. ERECTION AREAS | 1. DRIVE SHEET PILING AT LAUNCH-WAY | TO PREVENT EROSION OF LAUNCHWAY | MEDIUM | 200 - 500 | E1 |
| | 2. EXTEND SIDE LAUNCHWAYS INTO RIVER | INCREASE LOAD CAPACITY & DECREASE RISK OF VESSEL DAMAGE DURING LAUNCH | LOW | 50 - 200 | E2 |
| F. OUTFIT-TING AREAS | 1. NEW PIPE SHOP | BETTER MATERIAL FLOW & INCREASED PRE-OUTFITTING | HIGH | 50 - 200 | F1 |
| | 2. DRIVE SHEET PILING FOR OUTFIT-TING DOCK | TO EXTEND WORKING DISTANCE | MEDIUM | 500+ | F2 |
| | 3. REVISE POWER LINE OUTLAY | REDUCED CHANCE OF POWER OUTAGE | LOW | 10 - 50 | F3 |
| | 4. PURCHASE AUTOMATIC PIPE FABRI-CATION EQUIPMENT | INCREASED PRODUCTIVITY | LOW | 10 - 50 | F4 |
| G. SHIP REPAIR | 1. UPGRADE GAS-FREE PLANT | CONTINUED COMPLIANCE WITH STRICTER REGULATIONS | HIGH | 500+ | G1 |
| | 2. DRIVE SHEET PILING FOR REPAIR DOCKS | RELOCATE REPAIR | MEDIUM | 500+ | G2 |
| | 3. RELOCATE REPAIR FACILITIES | REDUCE COMMUNITY EXPOSURE TO AIR POLLUTION & LESS CONGESTION | MEDIUM | 200 - 500 | G3 |
| H. MATERIAL HANDLING | 1. CRANE TO HANDLE STRUCTURAL STEEL | (SEE A1 ABOVE) | - | - | A1 |
| | 2. EXTEND GANTRY RAILS | (SEE D4 ABOVE) | - | - | D4 |
| | 3. ADD RAILS, RELOCATE GANTRY FOR NEW O/F DOCK | REDUCED USE OF RIVER CRANES | LOW | 200 - 500 | H3 |
| | 4. ADD RAILS & GANTRY FOR RELOCATED REPAIR DOCK | REDUCED USE OF RIVER CRANES | LOW | 200 - 500 | H4 |
| | 5. STREET IMPROVEMENTS | BETTER VEHICLE TRAVEL | HIGH | 50 - 200 | H5 |
| | 6. PRIME MOVER FOR TRANSPORTER | TO PROVIDE ADEQUATE POWER | HIGH | 10 - 50 | H6 |
| | 7. NEW FORKLIFT FOR SHOP 5 | TO INCREASE TRANSPORTING CAPABILITIES | HIGH | 10 - 50 | H7 |
| I. ENGINEER-ING SUPPORT FACILI-TIES | 1. PURCHASE N/C DRAFTING MACHINE FOR MOLD LOFT | DECREASED MANPOWER | HIGH | 50 - 200 | I1 |
| | 2. ADDITIONAL OFFICE BLDG SPACE | CONSOLIDATE PERSONNEL | HIGH | 50 - 200 | I2 |
| | 3. PLOTTER & ASSOC. MACHINE TO PRODUCE WORKING DRAWINGS BY COMPUTER | AUTOMATED DRAFTING | LOW | 50 - 200 | I3 |
| | 4. GRAPHIC SYSTEM FOR 3D DRAWINGS | AUTOMATED DRAFTING | LOW | 10 - 50 | I4 |
| | 5. C.A.D. SYSTEM TO PRODUCE DRAWINGS | AUTOMATED DRAFTING | LOW | 50 - 200 | I5 |
| J. WARE-HOUSING | 1. INCREASE COVERED WHSE FACILITIES FOR STOCK | ADDITIONAL COVERED STORAGE SPACE | HIGH | 50 - 200 | J1 |
| | 2. BUILD/PURCHASE STORAGE PALLETS | BETTER MATERIAL HANDLING | MEDIUM | 10 - 50 | J2 |

COST RANGES ($000): 10 - 50 50 - 200 200 - 500 500+




LEVINGSTON FACILITY LAYOUT CHANGES

FIGURE 3-49

As a result of examination of each of these areas, and analysis of the effect of the proposed changes on other areas, the value of long range planning becomes apparent. In some cases, a change in one area conflicts with the improvement plans in another area. In other cases, a proposal in one area can complement that in another, but a modification of the original proposal may be necessary. This observation can be illustrated by examining the reasoning for changes in each area.

Steel Storage

It would be advantageous to Levingston to have the capability of unloading plates and structurals from barges at the material storage yard.

Steel Preparation

The two main problems needing correction in this area, and the proposed solution, include:

1) Problem: Sandblasting in open areas, creating dust and air pollution.

Proposal: Install enclosed blasting facility.

2) Problem: Plates are processed in blast and coat operations in a vertical position, but are stored horizontally before and after this operation.

Proposal A: Install vertical plate storage racks.

Proposal B: Replace the vertical shot blast facility with a horizontal type.

Fabrication Shops

Additional shop space, material handling capability, and plate forming capacity are desired.

Assembly

Additional shop space is desired to enclose assembly operations. A new location for assembly of deck houses is directly related to the plans for a future outfitting dock. Additional fabrication and assembly slabs are desired near the erection sites.

Erection Areas

Improvement to the side launchways is desireable for maintenance of its present condition and for increasing the capacity of its load-supporting capabilities for heavier ships.

Outfitting Areas

Improvements in outfitting facilities emphasize automated pipe fabrication and increased dock space. A new pipe shop with an orderly lay out and automated equipment is planned to increase pipe fabrication productivity.

Material Handling

Gantry service is planned as a supplement to expansions at the outfitting docks, repair docks, and unit assembly areas.

Engineering Facilities

The proposals for improvements in Engineering facilities relate mostly to requests for automated equipment. The N/C drafting machine is a high priority item. Other proposals relate to computer-aided design equipment.

Warehousing-

Levingston presently faces a shortage of covered warehouse space for its current business. Therefore, additional storage space is a high priority item. Also, plans are being formulated to build storage pallets for warehouse use similar to the pallets used for fabricated pipe storage.

LONG RANGE PLAN

This analysis of proposed improvements was summarized in Table T3-8. Subsequent to analyzing these desired changes, a chart giving advantages and disadvantages of each proposal was developed and is shown as Table T3-9. The purpose of this exercise is two-fold:

# FIGURE 3-9 EFFECTS OF PROPOSED IMPROVEMENTS

LEGEND:

- [XX] SIGNIFICANT DEGREE
- [X] MODERATE DEGREE
- [ ] NOT APPLICABLE

**ADVANTAGES**

| PROPOSED IMPROVEMENT | INCREASED PRODUCTIVITY | FEWER DELAYS | MORE FLEXIBILITY | BETTER QUALITY | IMPROVED CONTROL | EASIER PLANNING | SAFER CONDITIONS | FEWER PERSONNEL | REDUCED CONGESTION | IMPROVED MAT'L FLOW | BETTER MAT'L HANDLING | EXPANDS AREA | IMPROVED MAINTAINABILITY | RAPID PAYBACK | WEATHER PROTECTION | RELIEVES BOTTLENECK | POLLUTION CONTROL | EASIER STANDARDIZATION | REPLACES OBSOLETE EQUIPMENT | ELIMINATES AN OPERATION | UPGRADES APPEARANCE | AUTOMATES OPERATION | EXTENSION OF OTHER PROJECT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. STEEL STORAGE | | | | | | | | | | | | | | | | | | | | | | | |
| 1. CRANE FOR STRUCTURALS | X | X | | | XX | X | X | | XX | XX | XX | X | | | | | | X | | X | X | X | |
| 2. EXTEND STORAGE YARD | | | X | | | | | | X | X | XX | X | | | | | | | | | | | |
| B. STEEL PREPARATION | | | | | | | | | | | | | | | | | | | | | | | |
| 1. ENCLOSED BLAST HOUSE | X | XX | X | X | XX | X | XX | | X | X | X | | | | XX | | XX | X | X | | XX | X | |
| 2. VERTICAL PLATE RACKS | | X | | | X | | X | | XX | | XX | | | | | X | | X | | | X | | |
| 3. HORIZONTAL SHOT BLAST | X | | | | | | | | | | XX | | | | | | | X | | X | | | |
| C. FABRICATION SHOPS | | | | | | | | | | | | | | | | | | | | | | | |
| 1. CRANE - SHOP 5 | X | XX | | | | | | | XX | X | XX | | | | | X | | X | | | X | | |
| 2. 3000 TON VERTICAL PRESS | XX | X | XX | | X | X | | | XX | XX | | | | X | | XX | | X | X | | | X | |
| 3 EXTEND SHOP 6 | XX | XX | X | | XX | XX | X | | X | XX | X | | | X | XX | | | XX | | | XX | X | X |
| 4. CRANE - SHOP 6 | X | XX | | | | | | | XX | X | XX | | | X | | | | X | | | X | | |
| D. ASSEMBLY AREAS | | | | | | | | | | | | | | | | | | | | | | | |
| 1. ADD SHOP 7 - S/A'S | XX | X | X | | XX | XX | X | X | XX | XX | XX | | | X | XX | | | XX | | | XX | X | |
| 2. DECK HOUSE ASSY AREA | X | X | | | | X | | | | | XX | X | | | | | | | | | X | | |
| 3. EXPAND SLABS | | XX | X | | X | XX | | | XX | XX | | XX | | X | | X | | X | | | X | | |
| 4. EXTEND GANTRY RAILS | XX | X | X | | | X | | | | | XX | X | | X | | X | | X | | | | | X |
| E. ERECTION AREAS | | | | | | | | | | | | | | | | | | | | | | | |
| 1. SHEET PILING - LAUNCHWAY | | | | | | | | | | | | | XX | | | | | | X | | X | | |
| 2. EXTEND LAUNCHWAYS | | | X | | | | | | | | | X | | | | | | | | | | | |
| F. OUTFITTING AREAS | | | | | | | | | | | | | | | | | | | | | | | |
| 1. NEW PIPE SHOP | XX | X | X | X | XX | XX | X | X | X | XX | XX | X | | X | XX | | | XX | | | X | X | |
| 2. SHEET PILING - O/F DOCK (SEE H3 BELOW) | | | | | | | | | | | | | | | | | | | | | | | X |
| 3. POWER LINES | | X | | | | | | | | | | | XX | | | | | | X | | | | |
| 4. AUTO PIPE FAB EQUIPMENT | XX | X | XX | XX | XX | XX | | X | | X | | | X | X | | | | X | XX | | | XX | X |
| G. ENVIRONMENTAL & REPAIR | | | | | | | | | | | | | | | | | | | | | | | |
| 1. GAS-FREE PLANT | | | | | | | | | | | | | XX | | | | XX | | XX | | XX | X | |
| 2 SHEET PILING - REPAIR DOCKS (SEE H4 BELOW) | | | | | | | | | | | | | | | | | | | | | | | X |
| 3. RELOCATE REPAIR | | | | | | | | | XX | | X | | | | | | XX | | | | | | |
| H MATERIAL HANDLING | | | | | | | | | | | | | | | | | | | | | | | |
| 1. CRANE FOR STRUCTURALS (SEE A1 ABOVE) | | | | | | | | | | | | | | | | | | | | | | | X |
| 2 EXTEND GANTRY RAILS (SEE D4 ABOVE) | | | | | | | | | | | | | | | | | | | | | | | X |
| 3. GANTRY - O/F DOCK | X | X | X | | | X | | | X | X | XX | X | | | | | | | | | X | | X |
| 4. GANTRY - REPAIR DOCK | X | X | X | | | X | | | XX | | XX | | | | | | | | | | X | | X |
| 5. STREET IMPROVEMENTS | | | | | | | | | | | XX | | X | | | | | | | | XX | | |
| 6. HOVER FOR TRANSPORTER | | | | | | | | | | | XX | | X | X | | | | | | | | X | |
| 7. FORKLIFT FOR SHOP 5 | X | X | | | | X | | | | | XX | | | X | | X | | | X | | | | |
| I. ENGINEERING FACILITIES | | | | | | | | | | | | | | | | | | | | | | | |
| 1. N/C DRAFTER | X | | XX | XX | XX | X | | XX | | | | | | XX | | | | X | X | X | | X | |
| 2. ADD'L OFFICE SPACE | | | | | | X | | | XX | | | X | | | | | | | | | X | | |
| 3. PLOTTER FOR COMPUTER DRAWINGS | X | | XX | XX | X | X | | X | | | | | | | | | | X | XX | X | | X | X |
| 4. GRAPHIC SYSTEM - 3D DRAWINGS | X | | X | X | | X | | X | | | | | | | | | | X | XX | X | | XX | X |
| 5. C.A.D. SYSTEM FOR DRAWINGS | X | | XX | XX | X | XX | | X | | | | | | | | | | X | XX | X | | X | X |
| J. WAREHOUSING | | | | | | | | | | | | | | | | | | | | | | | |
| 1 MORE COVERED WHSE SPACE | | X | X | | XX | X | | | XX | X | XX | XX | | X | XX | | | X | | | XX | | |
| 2. STORAGE PALLETS | X | X | X | | XX | XX | | | XX | XX | XX | | | X | | | | X | | X | XX | | X |

**DISADVANTAGES**

| PROPOSED IMPROVEMENT | CAPITAL INVESTMENT | SLOW PAYBACK | ADDITIONAL PERSONNEL | INCREASED MAINTENANCE | INCREASED OPERATING COST | TRAINING COSTS | LAYOUT CHANGE REQUIRED | INCREASED MAT'L HANDLING |
|---|---|---|---|---|---|---|---|---|
| A. STEEL STORAGE | | | | | | | | |
| 1. CRANE FOR STRUCTURALS | XX | X | | X | | | XX | |
| 2. EXTEND STORAGE YARD | X | XX | | | | | X | |
| B. STEEL PREPARATION | | | | | | | | |
| 1. ENCLOSED BLAST HOUSE | XX | XX | | X | XX | | X | |
| 2. VERTICAL PLATE RACKS | X | XX | | | | | X | |
| 3. HORIZONTAL SHOT BLAST | XX | XX | | | | X | X | |
| C. FABRICATION SHOPS | | | | | | | | |
| 1. CRANE - SHOP 5 | XX | X | X | X | X | | | |
| 2. 3000 TON VERTICAL PRESS | XX | | X | XX | X | X | | |
| 3 EXTEND SHOP 6 | XX | | | | XX | | X | |
| 4. CRANE - SHOP 6 | XX | | | X | X | | | |
| D. ASSEMBLY AREAS | | | | | | | | |
| 1. ADD SHOP 7 - S/A'S | XX | | X | | XX | | XX | |
| 2. DECK HOUSE ASSY AREA | X | XX | | | | | X | |
| 3. EXPAND SLABS | X | | | | | | X | X |
| 4. EXTEND GANTRY RAILS | X | | X | X | | | X | X |
| E. ERECTION AREAS | | | | | | | | |
| 1. SHEET PILING - LAUNCHWAY | XX | XX | | | | | | |
| 2. EXTEND LAUNCHWAYS | XX | XX | | | | | | |
| F. OUTFITTING AREAS | | | | | | | | |
| 1. NEW PIPE SHOP | XX | | | X | X | | XX | |
| 2. SHEET PILING - O/F DOCK (SEE H3 BELOW) | | | | | | | | |
| 3. POWER LINES | X | XX | | | | | | |
| 4. AUTO PIPE FAB EQUIPMENT | X | | | X | X | X | X | |
| G. ENVIRONMENTAL & REPAIR | | | | | | | | |
| 1. GAS-FREE PLANT | XX | XX | | X | XX | X | XX | |
| 2 SHEET PILING - REPAIR DOCKS (SEE H4 BELOW) | | | | | | | | |
| 3. RELOCATE REPAIR | XX | XX | | | | | XX | |
| H MATERIAL HANDLING | | | | | | | | |
| 1. CRANE FOR STRUCTURALS (SEE A1 ABOVE) | | | | | | | | |
| 2 EXTEND GANTRY RAILS (SEE D4 ABOVE) | | | | | | | | |
| 3. GANTRY - O/F DOCK | XX | XX | X | XX | XX | X | X | |
| 4. GANTRY - REPAIR DOCK | XX | XX | X | XX | XX | X | X | |
| 5. STREET IMPROVEMENTS | XX | X | | | | | | |
| 6. HOVER FOR TRANSPORTER | X | | | | | | | |
| 7. FORKLIFT FOR SHOP 5 | | | | X | | | | |
| I. ENGINEERING FACILITIES | | | | | | | | |
| 1. N/C DRAFTER | X | | | X | | X | | |
| 2. ADD'L OFFICE SPACE | X | X | | X | X | | X | |
| 3. PLOTTER FOR COMPUTER DRAWINGS | X | X | | X | X | X | | |
| 4. GRAPHIC SYSTEM - 3D DRAWINGS | X | X | | X | X | X | | |
| 5. C.A.D. SYSTEM FOR DRAWINGS | X | X | | X | X | X | | |
| J. WAREHOUSING | | | | | | | | |
| 1 MORE COVERED WHSE SPACE | XX | | | | | | | |
| 2. STORAGE PALLETS | X | | | | X | X | X | |

1) To determine the merit of each proposal by weighing its advantages versus its disadvantages.

2) To compare the worth of each proposal relative to the other proposals being considered. This could lead to reassignment of the priorities of each item as listed in Table Tl-8.

Each advantage and disadvantage listed in Table T3-9 obviously does not carry equal weight. Furthermore, in some cases a single advantage for a particular proposal, such as for "pollution control", may overshadow all other advantages and disadvantages. The table was accordingly developed to indicate whether those advantages and disadvantages pertain to a given proposal to a significant degree, to a moderate degree, or as not applicable.

The list of items included as advantages and disadvantages are general in nature but are representative of the type of effects resulting from almost any proposed facility improvement.

The Levingston Long Range Plan, shown in bar chart form on Table T3-10, was drawn up following analysis of all data in Tables T3-8 and T3-9 and a' numerical analysis. The "group" category as determined by the numerical analysis is included in this table. Completion of this chart included a review of the cost of each proposal within specified ranges as given in Table T3-8. The budget plans can be developed for succeeding years based on these cost ranges and the Long Range Plan. This analysis is summarized in the chart below, which specifies the number of projects adopted during each of the next five years within each of the given cost ranges:

## TABLE T3-10

## LSCo LONG RANGE PLAN

| DESCRIPTION | GROUP* | COST** | FISCAL YEAR 1981 | FISCAL YEAR 1982 | FISCAL YEAR 1983 | FISCAL YEAR 1984 | FISCAL YEAR 1985 |
|---|---|---|---|---|---|---|---|
| N/C Drafting Machine | I | 50-200 | | | | | |
| Additional Covered Warehouse Space | I | 50-200 | | | | | |
| 3000 Ton Vertical Press | I | 500+ | | | | | |
| Extend Gantry Rails | II | 50-200 | | | | | |
| Forklift for Shop 5 | I | 10-50 | | | | | |
| Additional Engineering Office | III | 50-200 | | | | | |
| Expand Assembly Slabs | I | 200-500 | | | | | |
| Extend Shop 6 | I | 50-200 | | | | | |
| Prime Mover for Transporter | II | 10-50 | | | | | |
| Street Improvements | III | 50-200 | | | | | |
| New Pipe Shop | I | 50-200 | | | | | |
| Sheet Piling for Repair Docks | III | 500+ | | | | | |
| Sheet Piling for Outfitting Docks | III | 500+ | | | | | |
| Crane for Shop 6 Extension | II | 50-200 | | | | | |
| Crane for Structural Storage | II | 50-200 | | | | | |
| Warehouse Storage Pallets | I | 10-50 | | | | | |
| Enclosed Abrasive Blast House | II | 500+ | | | | | |
| Relocate Repair Docks | III | 200-500 | | | | | |
| Track and Gantry for Outfitting Docks | III | 200-500 | | | | | |
| Track and Gantry for Relocated Repair Docks | III | 200-500 | | | | | |
| Add Crane for Shop 5 | III | 50-200 | | | | | |
| Add Shop 7 for Sub-Assemblies | I | 500+ | | | | | |
| Plotter for Engineering Drawings by Computer | II | 50-200 | | | | | |
| Automatic Pipe Fabrication Equipment | I | 10-50 | | | | | |
| Graphic System for 3D Engineering Drawings | II | 10-50 | | | | | |
| Deck House Assembly Area | II | 50-200 | | | | | |
| Horizontal Shot Blast Facility | III | 500+ | | | | | |
| Revised Power Line Outlay | III | 10-50 | | | | | |
| C.A.D. System for Engineering Drawings | II | 50-200 | | | | | |

*Group determined by mathematical analysis.
**Cost Ranges ($000): 10-50 50-200 200-500 500+

NO. PROJECTS PER YEAR

| CAPITAL ($000) \ YEAR | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 10-50 | 1 | 1 | 1 | 1 | 1 |
| 50-200 | 4 | 3 | 2 | 2 | 2 |
| 200-500 | 1 | - | 1 | 2 | - |
| 500+ | 1 | 2 | 1 | 1 | 1 |
| MIN. $ | 910 | 1160 | 810 | 1010 | 610 |
| MAX. $ | 2350 | 2650 | 1950 | 2450 | 1450 |

IHI Approach

The method used by IHI to develop a long-range plan is similar in concept to that used by a U. S. shipyard. Formal proposals for major investment items originate with the Section Managers, who submit them to their Department Managers. After making priority selections, the Department Manager submits proposals to the General Superintendent of the shipyard. The proposals are further prioritized for the facility by the General Superintendent and submitted to the Head Office in Tokyo.

A committee meets semi-annually in Tokyo to discuss these major facility requests and to establish a three to five year plan. This plan is subject to review at these meetings. The committee is composed of members of the Facilities, Finance and Production groups. They tour each facility to observe the operations which are being proposed for renewal or improvement; then they review the costs and projected savings associated with the proposals, taking into consideration the previous year's budget, furture market potential, and company financial condition. The committee finally sets priorities for major facility investments and allocates budgets accordingly.

Those improvements requiring minor investment, such as new jigs, welding machines, etc., are handled separately from major investments. Each Department Manager is given a budget from which each Section Manager may suggest expenditures that would benefit his area. Department Managers issue approval for the expenditures based on need, cost, savings, and priority.

A major distinction from normal U. S. procedure is present, however. At IHI, separate budgets are prepared for two types of facility improvements:

1) Safety or Environmental Facilities

2) Manufacturing Facilities

Those facilities involving safety or environment are given first priority and are reviewed initially by the committee in Tokyo. This includes such items as scaffolding, life nets and pollution control equipment. Other facility improvements are expected to have tangible savings calculated, so that paybacks and returns on investments can be compared. These savings and cost figures are given a follow-up review by the committee to compare the actual with projected figures.

## CONCLUSION

The long-range facility plan for Levingston Shipbuilding Company has been developed in accordance with the usual practice of U.S. industry; future markets, machine innovations, government regulations, financial conditions and physical limitations were all considered. Concerning bulker-type ship production Levingston is emphasizing such fundamental items as:

1) Improved material flow
2) Better material handling equipment
3) Enclosed facilities
4) Automated equipment
5) Increased shop space, fabrication areas and buffer storage
6) Additional warehouse space
7) Increased outfitting capabilities
8) Improved pollution control facilities
9) Additional engineering facilities

The Levingston study of Facility Capabilities and Capacity, the improvements suggested by IHI, and the marketing objectives of the company have been considered in developing this long-range plan. The impact of changes as suggested by IHI are evident in the improvements already implemented to date as well as those being considered by Levingston for the next five years.

Long-range planning requires making decisions based on present knowledge to forecast future business directions. Management must be cognizant of the fact that conditions will not change exactly as predicted, but that the long-range plans are based on the best information available at the time the plan is developed. Therefore, it is evident that the long-range plan will require annual updating to take into consideration the unforeseen events that impact the organization's plans for growth. However, the value of long-range planning should be quite apparent in that it specifies the facility modifications and improvements that are required to meet the corporate marketing objectives. Development of a facility plan with corresponding timetables of events will hopefully prevent conflicts in allocations of resources and building of unsatisfactory facilities for the jobs to be done.

This is Levingston's most detailed long-range plan developed over an extended period. The company has an optimistic outlook for future development of the shipbuilding industry and is planning positive steps to meet the forthcoming challenges at Levingston. A great number of improvements have been made since the inception of the Technology Transfer Program two years ago. Many ideas of both Levingston and IHI personnel have been implemented. The successful implementation of these ideas coupled with the enthusiasm for application of new techniques and concepts indicate the acceptance and continued development of long-range plans at Levingston in the years ahead.

# SECTION 4

# STANDARDS

# SECTION 4

# STANDARDS

## PRINCIPLES OF STANDARDIZATION

Everyone today recognizes the values of standardization. Virtually every handbook or textbook on manufacturing systems contains a chapter or section on standardization and the benefits that result therefrom. This study revealed no new technology, but like other reports in this series, it does reveal a superior achievement in the application of known standardization techniques and methods within the marine industry.

IHI's philosophy is that any large scale standardization effort must begin in the design stage. Because the associated manufacturing facilities already exist, standardization of design must be accomplished in harmony with production limitations and capabilities.

From standardization of the product, the effort expands. Material is coded, vendors selected, material purchased, production plans determined, and schedules set. For each activity, hundreds of pieces of information pass through the system. The opportunity to reduce the amount of data handled at every level in the manufacturing process depends directly on the extent of standardization. Reduction in data handled also reduces the occurrence of errors and misunderstandings.

Standardization of the product allows the production facilities to be specialized. Economy, through the application of mass production techniques, is well known. The development of conveyors, jigs, fixtures, the familiarity of the workers with the equipment, work methods, and ship design are all greatly enhanced as the ship design is standardized.

Facilities are organized in one of three ways according to the layout of equipment and the movement of material:

1) Fixed-position layout where the product stays in one position and material is brought to it;

2) Process layout where material is routed to different areas where specialized processes (different for each area) are carried out; and

3) Product flow layout where work-in-progress is moved by conveyor or similar means from one work station to the next.

Shipbuilding *uses* all three. The last several decades has shown an overall movement from the first and second to the second and third in the attempt to apply mass production technology, i.e., from ship construction to ship production. IHI has made a concerted effort to carry the evolution as far as possible..

Recently American and European manufacturers in other industries have introduced the concept of "Group Technology". IHI uses the term to include family manufacturing, process-lanes, worker groups, and product-work-breakdown. A basic component of group technology is the set of requirements imposed on the parts classification and coding system.

This coding leads directly to computerization. In fact, successful computerization of a shipbuilding data base is directly correlated with successes in standardization. Computer-aided design, computer-aided manufacturing (CAD/CAM) and computer-aided process planning (CAPP) all require standardized data in computerized files.

## IHI'S STANDARDIZATION EFFORTS

Overall, IHI views its standardization efforts as:

1) a long-range planning effort
2) a means of resolving recurring problems
3) Documentation of things learned
4) cost reduction

Standards are a tool for communication. Design standards developed with the aid of production personnel formalize design practices best suited for both design and production. These standards in turn provide "instant experience" to new personnel. Material standards are the shorthand notes between Design and Purchasing Departments reducing the volume of descriptive data as well as reducing the variety of materials and supplies maintained in inventory.

In the same way, tolerance standards provide a clean and definite set of agreements between the design, production, and quality assurance groups. Everyone knows what is required as well as having addressed and settled the questions of how much quality can be achieved for what cost.

Process standards cover not only basic marking, cutting, and welding processes but also assembly methods up to and including assembly specification plans which detail the methods to be followed during fabrication, assembly and erection. The most effective methods (and alternatives) are documented forming the basis for all future plans.

Having covered the what and the how, cost standards document the how much and how long. All of IHI's long-range and detailed schedules depend upon accurate feedback and documentation of the manhour costs from design through delivery. Consistency in product design, consistency in planning methodology, and consistency in production methods lead to greater consistency and lower costs in returned manhours.

The task for continually reviewing, updating old standards, deleting obsolete ones, and creating new standards is recognized as vital and is a basic assignment for all members of the organization.

## APPLICATION OF IHI TECHNOLOGY

At the start of the TTP program, a parallel effort was being made by Levingston to reorganize, codify and streamline all phases of documentation. Figure 4-1 illustrates the pyramid structure of that effort. Standards then as now formed the base. This arrangement was overwhelmingly and repeatedly confirmed by the practices and methods utilized by IHI.

INTEGRATED HIERARCHY OF DOCUMENTATION

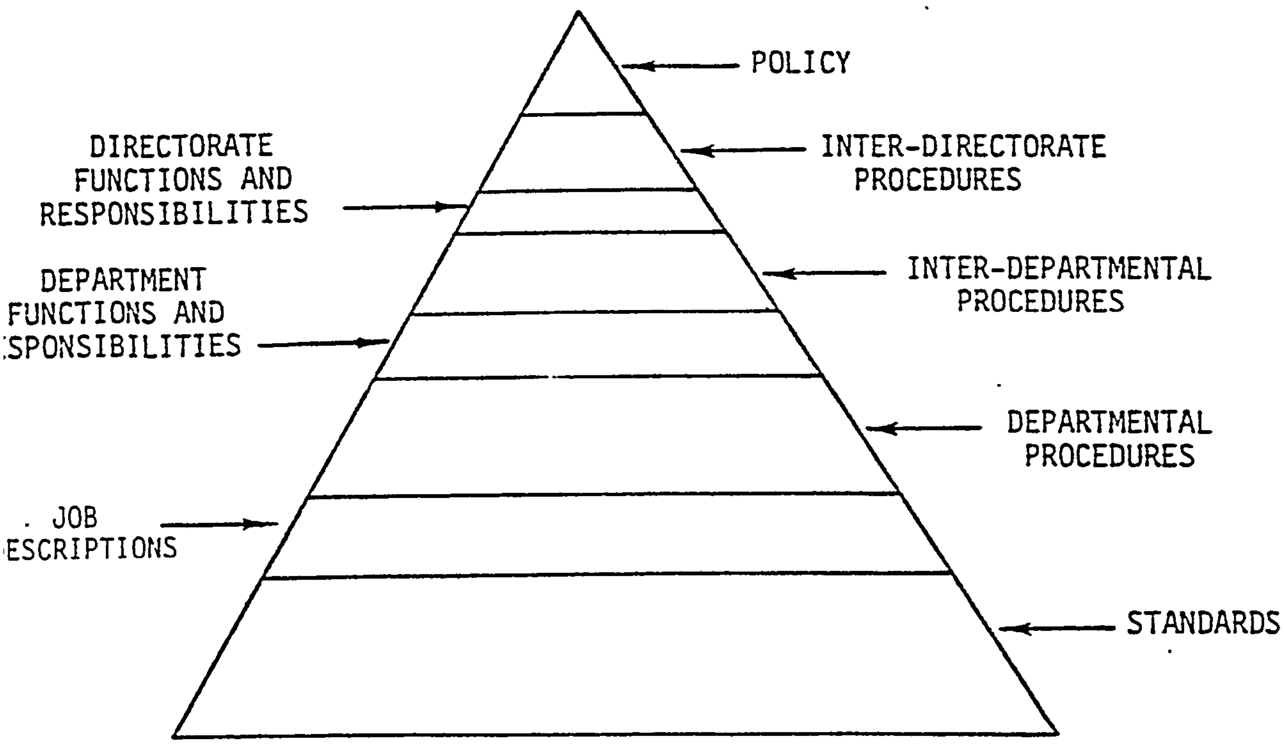



**FIGURE4-1**

# DESIGN STANDARDS

## DEVELOPMENT OF NATIONAL AND SHIPYARD STANDARDS

That a significant difference exists between the role of the governments of Japan and the U. S. in promoting national standards is not new to U. S. shipbuilders. The Japanese Industrial Standardization Law gives that government the authority to select a designated commodity or designated processing technique for a product. This is done when the quality of the commodity or product must be guaranteed due to its widespread use of manufacture.

IHI developed its own set of standards to supplement the JIS: in the early 1960's, a major effort to establish in-house standards was initiated. Special task groups were organized in several departments of each yard--Design, Fabrication, Assembly, Erection and Outfitting, etc.--each with the requirement to produce several standards per month. This was continued over a two-year period at which time about 80 percent of IHI's current standards were identified and draft standards prepared.

The development of yard plans from the key plans depends heavily on standardization. Numerous plans and schedules must be developed. A detailed schedule of supplying drawings to the yard is prepared as the "Design Procedure and Drawing Supply Schedule" for a particular ship type and is referred to as a "Management Standard".

Standards on coding, design practices, production practices, drafting room procedures, material specifications and so forth are reduced in size and bound in book form for ready reference by designers and drafters. These ready reference manuals put the shipyards accumulated experience directly in the hands of those who need them. They also help to ensure uniformity of application within departments and compatibility among departments.

## ORGANIZATION AND USE OF IHI STANDARDS

For the purposes of the TTP, IHI design standards were classified into three categories based on the type of information given:

1) General definition and material coding standards

2) Detailed design standards

3) Production standards

# MATERIAL STANDARDS

## INTRODUCTION

One of the most striking aspects of shipbuilding is the large quantity and wide range of materials required. A vast amount of information is required to be passed among the departments and to vendors. IHI has developed standards both as a means of communication and as basis for a computerized data base.

This section describes how material standards fit into the IHI system.

## MATERIAL STANDARDS AND THE DESIGN PROCESS

For the designer, the material standards perform two functions. First, they tell him what is stocked (or available at short notice) and second, the interfacing requirements for components and equipment, e.g., machinery and foundations, valves and piping, etc. For raw materials, there are corresponding design application standards specifying the range and increment of sizes to be used.

Designers specify material in one of three ways:

1) By code referencing a material standard (Standard Drawing) Material requisition classification T.

2) By purchase order specification. Normally, off-the-shelf items in accordance with national standards or vendor-supplied information. Material requisition classification P.

3) By developing Fabrication Drawings for material to be manufactured by subcontractors. Material requisition classification D.

It is by intent that the number of materials specified by standards (T) be much larger than the number specified by purchase order (Type P) or by Fabrication Drawing (Type D).

As discussed in the next section, reducing the number of different sizes for either raw materials or components leads to reduced costs for the material control system. This has an adverse effect on the designer, however, as he no longer has a wide a range of sizes from which to choose. Selecting the next size larger for an item to meet a requirement means over-design or over-specification in many cases. IHI design engineers quite readily accept this negative impact on design as part of their responsibility to reduce total shipbuilding costs.

## MATERIAL STANDARDS AND THE MATERIAL CONTROL SYSTEM

The typical IHI material control system is composed of several subsystems:

- -Data entry subsystem
- -Remainder appropriation subsystem (use up leftover materials prior to new purchases)
- -Leveling and balancing subsystem
- -Purchasing subsystem
- -Delivery control subsystem
- -Material receipt and inventory subsystem
- -Material issue subsystem (including palletizing)

Along with the material codes and material requisition codes, IHI also classifies material for inventory control purposes. The classifications are:

1) Stocked Materials (S-Material)
   General materials used on various kinds of vessels such as bolts, nuts, joints, packings, small chain, etc. This material is always on hand in a warehouse with set stocking levels periodically adjusted item by item as historical demand indicates.

2) Allocated Material (A-Material)
Materials used for a specific vessel such as special valves, special pipes, or equipment. The type and quantity is specified item by item design and purchased in the quantity specified.

3) Allocated Stock Material (AS-Material)
Materials used for a specific vessel but needed in large quantities such as pipe, flanges, elbows, etc. The material is ordered in leveled lots with total quantity determined as the design is finalized.

There is a definite relationship between the material requisition codes (T, P, and D) and the material control classes (S, AS, and A). Materials specified by standards (T) fall into all three of the control classes while those specified by the other two methods (P and D) are designated as Allocated Stock (AS) materials.

IHI has made consistent and concerted efforts to reduce the amount of material in inventory whether it be in the warehouse, steel stock yard or in-process..

Many major U. S. yards have realized reductions in inventory carrying costs (as well as the acreage) by standardizing the numbers of different sizes and thicknesses of steel plates. IHI has carried this process to other materials which in itself was a major driving force in the establishment of material standards.

LEVINGSTON APPLICATION

As a result of the study, Levingston developed its own version of a standard for sizes of steel plates and has started to revise its material stock catalog.

## TOLERANCE STANDARDS

### INTRODUCTION

In order to understand the importance and the development of tolerance standards at IHI, the Accuracy Control concept must first be explained.

The objectives of Accuracy Control are:

1) To maintain the highest accuracy possible at each stage of production of every fabricated piece, part, sub-assembly, assembly and erected unit.

2) To minimize the work at the erection stage.

3) To consistently improve the production stage to yield the highest accuracy in all products.

The main goal of Accuracy Control is to perfect each production method, technique and process to such a degree that each worker activity has definitive standards to be achieved, a prescribed method of measurement for finished material, and a continuous flow of information between activities resulting in the constant improvement of product quality and production efficiency.

### TYPES OF TOLERANCE STANDARDS AT IHI

Tolerance standards at IHI have evolved from actual production practices over many years and many a series-run of ships. For many ship types, standard tolerances are firmly established and require little, if any, modification. In these cases, Accuracy Control Engineers simply review ship specifications for any requirements that would cause a change to those already in practice. In the case of a new ship type, standard tolerances are reviewed and changes effected where necessary to comply with specification requirements or with differing technical requirements for that ship. Generally, no major revision of tolerance standards is required even on new ship types.

## DEVELOPMENT OF TOLERANCE STANDARDS

IHI uses Accuracy Control check sheets to develop a history of recorded data on checks of fabricated, assembled and erected pieces. With a log containing over fifteen years' collection of data, IHI was able to develop standard and tolerance tables for each of these processes on all units. The values of these tolerances are generally stricter than those established by the ship's owners and the Japanese classification societies. The JSQS (Japanese Shipbuilding Quality Standards) is the main source for Japanese shipbuilding standards.

## EXAMPLES OF TOLERANCE STANDARDS

Examples of tolerance standards for the two types of control, regular and special control, are provided as Figures 4-2 and 4-3.

## FEEDBACK SYSTEM - STATISTICAL ANALYSIS

From analysis of the measurement data, appropriate action is taken by the Accuracy Control Engineer through feedback of information to the applicable department or group. This feedback is a vital loop in the overall Accuracy Control scheme and not only prevents errors from recurring, but provides the action necessary to the continuing improvement of product and production system. Examples of this feedback are: a change to the dimension of added material requires a modification to the working drawing, therefore, Engineering is so notified; an addition of Baselines in the output of the mold loft requires feedback to the loft; a change in the fabrication method. or the platform at assembly or welding procedure requires feedback to Production and to the Planning and Design Staff responsible for a given workshop.

| SHOP | ITEMS TO BE CHECKED | ALLOWABLE TOLERANCE | FREQUENCY OF MEASURING |
|---|---|---|---|
| Marking & Gas Cutting | | | |
| (Section) | *Line for gas cutting of angles (after cutting) | e = ± 1/32" | 5 pc/day |
| | *Length of angles (after cutting) | e = ± 1.5/64" | 5 pc/day |
| (Internal Member) | *Normality after gas cutting (right angle) | e = ± 2mm per 1500mm | 5 pc/day |
| | *Line for gas cutting | e = ± 1/32" | " |
| | *Length after gas cutting | e = ± 3/64" | " |
| | *Width after gas cutting | e = ± 3/64" | " |
| <u>Flame Planer</u> | *Length & Width after cutting | e = ± 1.5/64" | 5 pc/day |
| (Flat Shell Plate Flat Plate | *Straightness | e = ± 1/64" | 2 pc/week |
| | *Bevel Angle | e = ± 2.0 deg. | 5 pc/day |
| | *Normality (Right Angle) | e = ± 2mm per 1500mm | 2 pc/week |

FIGURE 4-2

TOLERANCE STANDARDS REGULAR CONTROL (EXAMPLES)

| SHOP | ITEM | TOLERANCE | FREQUENCY OF MEASURING | REMARKS |
| --- | --- | --- | --- | --- |
| <u>ERECTION</u><br><br>Bottom Shell | *Positioning (Length wise)<br>Measure on the check points on berth | e = ± 1/8" | Starting unit only | |
| | *Positioning: (Height)<br>Measure at the most forward frame (2 points) | e = ± 1/4" | All Units | By Gauge |
| | *Level: (Between left side and right side)<br>Measure on the points at forward edge | e = ± 1/4" | All Units | Pay attention to twist |
| | *Positioning: (Between left side and right side) Measure at the forward butt | e = ± 1/8" | All Units | Plumb down to the base line on berth |
| | *Connecting part between units: Check the bevels at seams and butts | e = ± 1/8" | All Units | |
| | *Discrepancy of ship's center | e = ± 1/8" | All Units | Measuring by transit |

FIGURE 4-3

TOLERANCE STANDARDS SPECIAL CONTROL (EXAMPLES)

## LEVINGSTON APPLICATIONS

The adoption of unitized construction of vessels increases the importance of tolerance standards to insure proper erectability of assembled units. IHI engineers contributed to the development of tolerance standards for Levingston compatible with the unit system being implemented. Levingston engineers reviewed IHI's tolerance standards for ideas on types of standards, format of information, and specific tolerance allowances.

Levingston published standards for welding and for joint details, including tolerance limit values, prior to TTP. These standards specify edge preparation, fitting and welding techniques as allowed in the welding procedure qualification process. Since inception of TTP, Levingston has issued tolerance standards for hull construction in the areas of hull details (e.g., fitting accuracy), ship design (overall hull dimensional deviations), in piping (e.g., butt weld fitting material requirements), and in flat panel assembly (e.g., structural alignment). Examples of Levingston's tolerance standards are given as Figures 4-4 and 4-5. Tolerances are an indication of the lowest acceptable level of performance and not to be interpreted as an allowable standard for everyday work.

## CONCLUSION

Tolerance standards for a given shipyard must reflect the conditions, equipment and methods of operation at that particular facility. The standards are invaluable to maintain a satisfactory program of accurate workmanship. The data collection system used to develop these standards, the flow of information to appropriate departments, and the standards devised by classification groups or used at other locations are transferable as guidelines for a facility to use in initiating its own program.

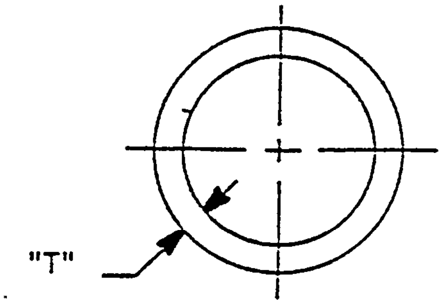
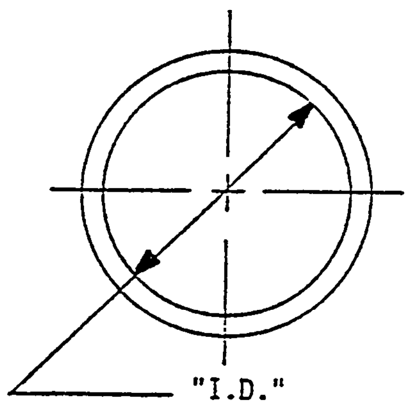
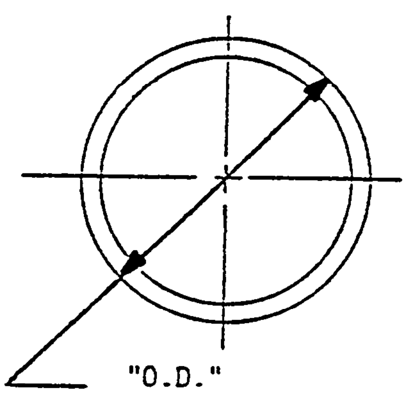
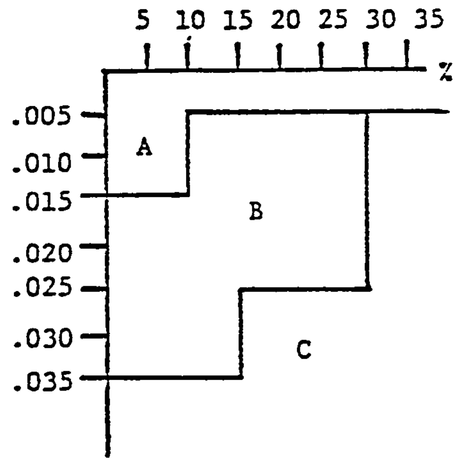
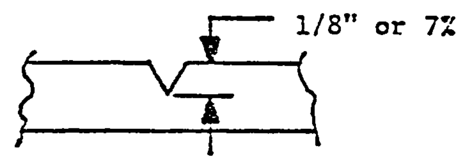
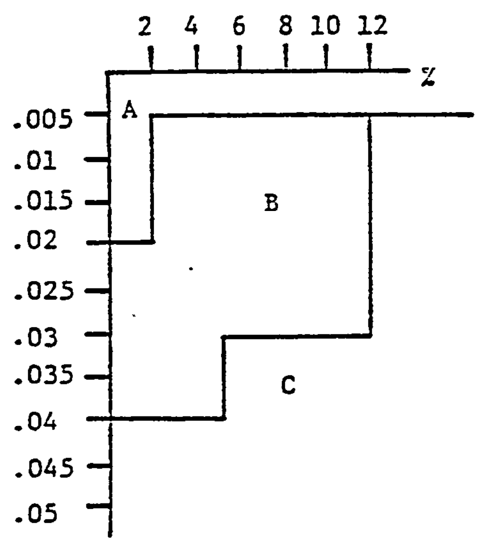
| OBJECT | | MATERIAL | | |
|---|---|---|---|---|
| TYPE | SUB TYPE | ITEM | TOLERANCE LIMIT | REMARKS |
| PIPE AND BUTT WELD FITTINGS | WALL THICKNESS |  | T = THICKNESS<br><br>THE WALL THICKNESS SHALL NOT AT ANY POINT BE LESS THAN 87 1/2% OF THE NOMINAL THICKNESS. | PER ANSI B16. |
| | INSIDE AND OUTSIDE DIAMETERS |  | I. D. = INSIDE DIA.<br><br>A. UP TO 2 1/2" -- ± 1/32"<br><br>B. 3" TO 8" - ± 1/16"<br><br>C. 10" TO 18" - ± 1/8"<br><br>D. 20" TO 48" - ± 3/16" | PER ANSI B16. |
| | |  | O.D. = OUTSIDE DIA.<br><br>A. UP TO 2 1/2" +1/16" - 1/32"<br><br>B. 3" TO 4" +1/16" -1/16"<br><br>C. 5" TC 8" +3/32" -1/16"<br><br>D. 10" TO 18" +5/32 -1/8"<br><br>E. 20" TO 48" +1/4" -3/16" | PER ANSI B16.9 |

FIGURE 4-4 LEVINGSTON TOLERANCE STANDARDS - EXAMPLE

<table>
<tr><th colspan="2"></th><th colspan="2">MATERIAL</th></tr>
<tr><th>TYPE</th><th>SUB TYPE</th><th>ITEM</th><th>REMARKS</th></tr>
<tr><td rowspan="2">SURFACE FLAW</td><td>PIT</td><td>SURFACE AREA RATIO<br>

DEPTH<br>(Decimal of Inches)</td><td>1) GRADE "A" - SLIGHT NO REPAIR NECESSARY.<br>GRADE "B" - MEDIUM DISORDER, REPAIR IF NECESSARY.<br>GRADE "C"- SERIOUS DISORDER NEEDS REPAIR.<br>2) REPAIR METHOD - GRIND OR WELD & GRIND.<br>MILL STANDARD = 1/8" or 7% OF PLATE THICKNESS.<br>
</td></tr>
<tr><td>FLAKING</td><td>SURFACE AREA RATIO<br>

DEPTH<br>(Decimal of Inches)</td><td>1) GRADE "A" - SLIGHT NO REPAIR NECESSARY.<br>GRADE "B" - MEDIUM DISORDER REPAIR IF NECESSARY.<br>GRADE "C" - SERIOUS DISORDER. NEEDS REPAIR.<br>2) REPAIR METHOD - SAME AS PIT REPAIR</td></tr>
</table>

FIGURE 4-5 LEVINGSTON TOLERANCE STANDARDS - EXAMPLE

The IHI system was discovered to be very comprehensive, containing rigid standards by comparison to Levingston's past guidelines for tolerances.

The feedback system is an essential ingredient for developing, maintaining and revising tolerance standards. The system relies on a substantial amount of data collection, but amply compensates for itself by providing information vital to sustaining a reliable accuracy control program. This becomes especially visible at the assembly and erection stages, where ease of fit-up is directly related to the accuracy of work in the preceding stages. Improvements in this area easily justify a comprehensive program of well-established tolerance standards for any shipyard.

## PROCESS STANDARDS

A process standard is an established method prescribing a uniform sequence for performing an operation or set of operations.

This definition is presented in order to distinguish a process standard from a cost standard as they are described in this report. The main distinction can be expressed by stating that a measurement of performance of a "process standard" results in a *"cost* standard".

A process is an operation or sequence of operations performed on a component which changes the characteristics of the component.

In this context, then, a process may be broad (e.g., cutting, assembly) or specific (N/C cutting, flat panel assembly).

IHI maintains a wealth of process standards in the forms of manuals, operating guidelines, written procedures, instructions, etc., which are used throughout the shipbuilding process. They also maintain numerous records, lists and logbooks which are used to develop these standards.

### SIGNIFICANT DIFFERENCES (IHI vs. LEVINGSTON) & SUGGESTED IMPROVEMENTS

Within the processes, the greatest points of differences were found to be in the sub-assembly and assembly areas. Specific differences and recommended improvements for standardization of the processes included the following:

1) Maximize assembly of small pieces at the sub-assembly stage, thereby decreasing the amount of this minute work required at assembly stages.

2) Classification of assembly work into the categories previously listed with the following objectives:

-Maximum utilization of facilities to obtain the highest productivity.

-Achievement of the most performance by means of having workers permanently stationed at fixed work sites.

3) Utilization of welding in the flat position, in order to obtain good performance and high productivity.

In the area of outfitting, specific recommendations made by IHI to improve on the standardization concept concerned greater utilization of:

1) Pre-Outfitting: Module Stage

2) Pre-Outfitting: On-Unit Stage

3) Pipe Fabrication: In the Shop

This section on Process Standards is specifically aimed at the aspect regarding standard work flow in each area, particularly the detail procedures for each area. This procedure requires analysis of the facilities and the work breakdown assignments, examinations of methods for their description, and improvement and identification of the skills and equipment needed. The process standards will then be used to develop time standards, cost standards and manpower requirements to analyze productivity and to provide data for planning and scheduling purposes. The objective of standardizing processes is to organize procedures in a uniform and repetitious manner for use in formulating accurate schedules in the easiest fashionable manner.

PRELIMINARY PLANNING

Process standards will deal with the procedures specifying the methods to be employed. These consist of rough procedures drawn up in the early stages as planning efforts in the assignment of work within gates, and the detail procedures designating the method of constructing each assembly unit.

These process standards are used to develop cost standards, which are vital elements toward establishment of accurate schedules.

## DETAIL PROCEDURES

The purpose of specifying detail procedures is to establish efficient, uniform, sequential patterns of work plans for field personnel to follow. These procedures aid in job preparation by stipulating in advance the necessary materials, equipment, jigs and components that will be needed. These guidelines assist foremen and improve the working environment in the following ways:

1) Establishes a pre-determined standard method of operation.
2) Prescribes the most effective sequence of activities.
3) Specifies arrangement and uses of necessary jigs and fixtures.
4) Issues warning notes to exercise care in the work being done in order to avoid a future problem.
5) Provides consistency between foremen, between shifts, between departments, etc.
6) Designates details of work within a specific area and its relationship to other supporting work.
7) Gives a broad overview of the total scope of work for better understanding of each individual segment.

## ASSEMBLY PROCEDURES AND GUIDELINES

Formal procedures of specified assembly plans have been written by industrial Engineering and issued to the Production Departments. These procedures have been issued for each hull under construction since the first bulker (including duplication for like hulls). The procedures specify the assembly methods for each typical unit in the hull, complete with sketches, detailed instructions, sequence of steps, crucial dimensions, arrangements of the unit with jigs, and other necessary information. An example of a typical Assembly Procedure and Guideline issued for the construction of the bulker is given as Figure 4-6.

This procedure has been welcomed by the Production Department as an effective aid to promote uniform methods and procedures, to visualize the assembly process, to help avoid problems in assembly and accuracy control, and to plan their work.

## WORK MANUALS

It is Levingston's plan to issue work manuals for each gate or set of related gates. These work manuals are visualized to contain such information as working procedures, gate layout, material flow, data collection, forms, statistical reports and charts generated, quality standards, safety precautions, manpower assignments, and the like.

## CRAFT HANDBOOKS

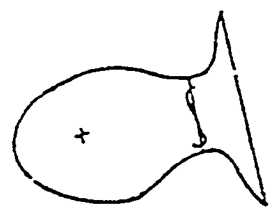
Another desirable form of standards document is a handbook for each craft. IHI issues handbooks to each worker specifying guidelines to follow in the performance of his work. These handbooks contain both general and specific guidelines concerning such subjects as work tools, job procedures, safety precautions, quality standards, etc.

The writing and issuing of these types of handbooks are not foreseen in the near future for Levingston but are prospective goals. Information for welders' use is currently being generated that would be included in this type of handbook.

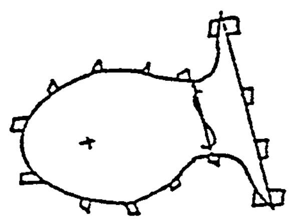
## TYPICAL CONSTRUCTION ASSEMBLY SKETCH

### LSCo ASSEMBLY PROCEDURES AND GUIDELINES FOR UNIT 241

1. FIT AND WELD FR. 10 PLATE (BOTH SIDES) ON FLAT SLAB.



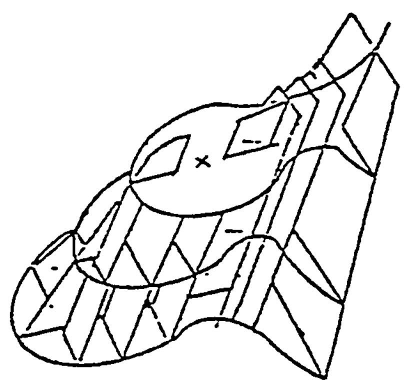
2. SET NECESSARY SUPPORTS AT LEAST 10" HIGH. SET FR. 10 PLATE ON SUPPORTS.



3. SET AND FIT STRUCTURALS, FLAT AND FRAMING ON FR. 10 PLATE.

   WELD INTERNALS.

4. PUT CASTING ON.



5. PUT SHELL PLATE ON IN SEQUENCE OF A-B-C-D-E-F AND FINISH WELDING.

   PUT SHELL PLATES G-H-I-J ON AND FINISH WELDING.

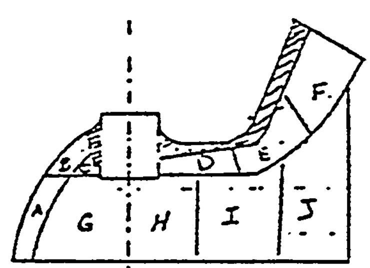



FIGURE 4-6

# COST STANDARDS

## INTRODUCTION

One of the most impressive aspects of the IHI production system is the remarkable adherence to schedule. The development of precise scheduling techniques is the result of carefully planned, thoroughly documented information systems which are devised to develop standard data. The process standards discussed in the foregoing section specify the proper methods to be followed which result in procedural standardization. The subsequent step is the measurement of performance resulting from application of these process standards, amounting to standardized units of time per product, or numbers of product per time element, which are the basis for cost standards.

In conjunction with establishment of standardized work procedures, or process standards, a measurement system of the rate of production results in performance standards. These standards form the basis of cost standards, which are defined in this report as:

A cost standard is a measured rate of production for a given process to be used in planning, scheduling and estimating activities and to calculating the cost of the process.

Examples of cost standards in the shipbuilding process include: manhours per ton, inches per minute (cutting), feet per hour (welding), etc.

## DOCUMENTS

There are a number of status reports recommended by IHI for use in the development and application of cost standards:

1) Manhour Collection Sheets

    a) Daily record of manhours spent on each unit, by worker name. (See Figure 4-7)

GATE ______ FOREMAN ______________________ SHIFT ______________

| WORKER / UNIT | I.K. | B.T. | E.F. | T.R. | S.S. | H.K. | C.L. | R.M. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | 8 | 8 | 8 | 8 | 8 | 4 | 4 | 4 | | | | | 52H |
| 111 | | | | | | 4 | 4 | 4 | | | | | 12H |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

FOREMAN ______________________ SHIFT ______________

| WORKER / UNIT | I.K. | B.T. | E.F. | T.R. | S.S. | H.K. | C.L. | R.M. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | 8 | 8 | 8 | 8 | 8 | | | | | | | | 40H |
| 111 | | | | | | 8 | 8 | 8 | | | | | 24H |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

DAILY MANPOWER RECORD (SAMPLE)

FIGURE 4-7

b) Monthly record, composed of summation of data on daily records. (See Figure 4-8)

2) Efficiency Records on productivity, e.g., meters/hour ratio on welding. (See Figure 4-9)

3) Blackboards--Displays posted in designated areas specifying schedules, productivity, quality or work, etc. (See Figure 4-10)

## DEVELOPMENT OF COST STANDARDS

The purpose for developing process standards and cost standards from the IHI viewpoint is for use in the following applications:

1) Base data for estimating manhour requirements

2) Base data for estimating periods of completion for jobs

3) Base data used toward determining needed improvements in equipment and facilities

4) Base data used in status reporting and applied toward improving productivity.

5) Educational material and training aids for field personnel

The data used to calculate cost standards are derived from the previously developed process standards. The approach recommended by IHI for the determination of process standards first involves classification of the elements to study. The basic elements regarding hull construction are listed in Table T4-1.

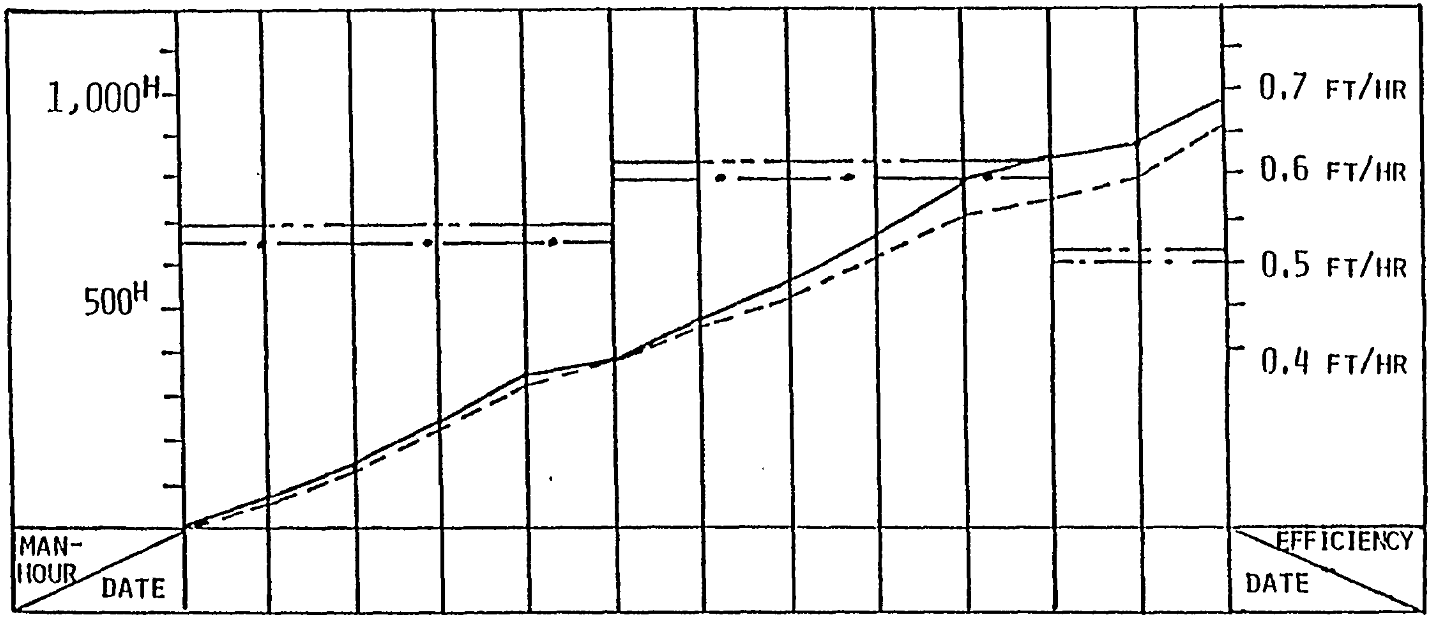
By studying and analyzing these basic elements of the shipbuilding cycle, a shipyard can determine the control parameters it may best utilize for each element. This can be determined by the data collected at the facility, the measurement technique it can best employ with the resources it has available, and the accuracy and applicability of the data measured. Table T4-2 specifies the measurement parameters used at IHI for each working stage. Also included

CRAFT: FITTERS

| UNIT | W.L. (FT) | ISSUED MAN-HOURS | DAILY MANHOURS CHARGED | | | | | | | | | | | | | | | | | | | | TOTAL MAN-HOURS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6/9 | 10 | 11 | 12 | 13 | 16 | 17 | 18 | 19 | 20 | 23 | 24 | 25 | 26 | 27 | 30 | 7/1 | 2 | 3 | 4 | |
| 101 | 470 | 115 | | | | 16 | 16 | 32 | 32 | 32 | 16 | 16 | | | | | | | | | | | $128^{H}$ |
| 111 | 520 | 125 | | | | | | | | 16 | 16 | 32 | 32 | 32 | 16 | | | | | | | | $144^{H}$ |
| 121 | 485 | 120 | | | | | | | | | | | | | 16 | 32 | 32 | 32 | 24 | | | | $136^{H}$ |
| 131 | 490 | 120 | | | | | | | | | | | | | | | | | 8 | 32 | 32 | 32 | $104^{H}$ |
| | | | | | | | | | | | | | | | | | | | | | | | |

| UNIT | W.L. (FT) | ISSUED MAN-HOURS | DAILY MANHOURS CHARGED | | | | | | | | | | | | | | | | | | | | TOTAL MAN-HOURS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 7/7 | 8 | 9 | 10 | 11 | 14 | 15 | 16 | 17 | 18 | 21 | 22 | 23 | 24 | 25 | 28 | 29 | 30 | 31 | 8/1 | |
| 131 | 490 | $120^{H}$ | 16 | | | | | | | | | | | | | | | | | | | | $120^{H}$ |
| 141 | 465 | $115^{H}$ | 16 | 32 | 32 | 16 | 16 | 16 | | | | | | | | | | | | | | | $128^{H}$ |
| 151 | 515 | $125^{H}$ | | | | 16 | 16 | 16 | 32 | 32 | 16 | | | | | | | | | | | | $128^{H}$ |
| 161 | 510 | $120^{H}$ | | | | | | | | | 16 | 32 | 32 | 32 | 16 | 16 | | | | | | | $144^{H}$ |
| 171 | 495 | $120^{H}$ | | | | | | | | | | | | | 16 | 16 | 32 | 16 | 16 | | | | $128^{H}$ |

FIGURE 4-8 MONTHLY REOCRD OF MANHOURS (SAMPLE)




LEGEND

AVERAGE (ACTUAL)

AVERAGE (GOAL)

CUMULATIVE (ACTUAL)

CUMULATIVE (GOAL)

EFFICIENCY CHART

FIGURE 4-9

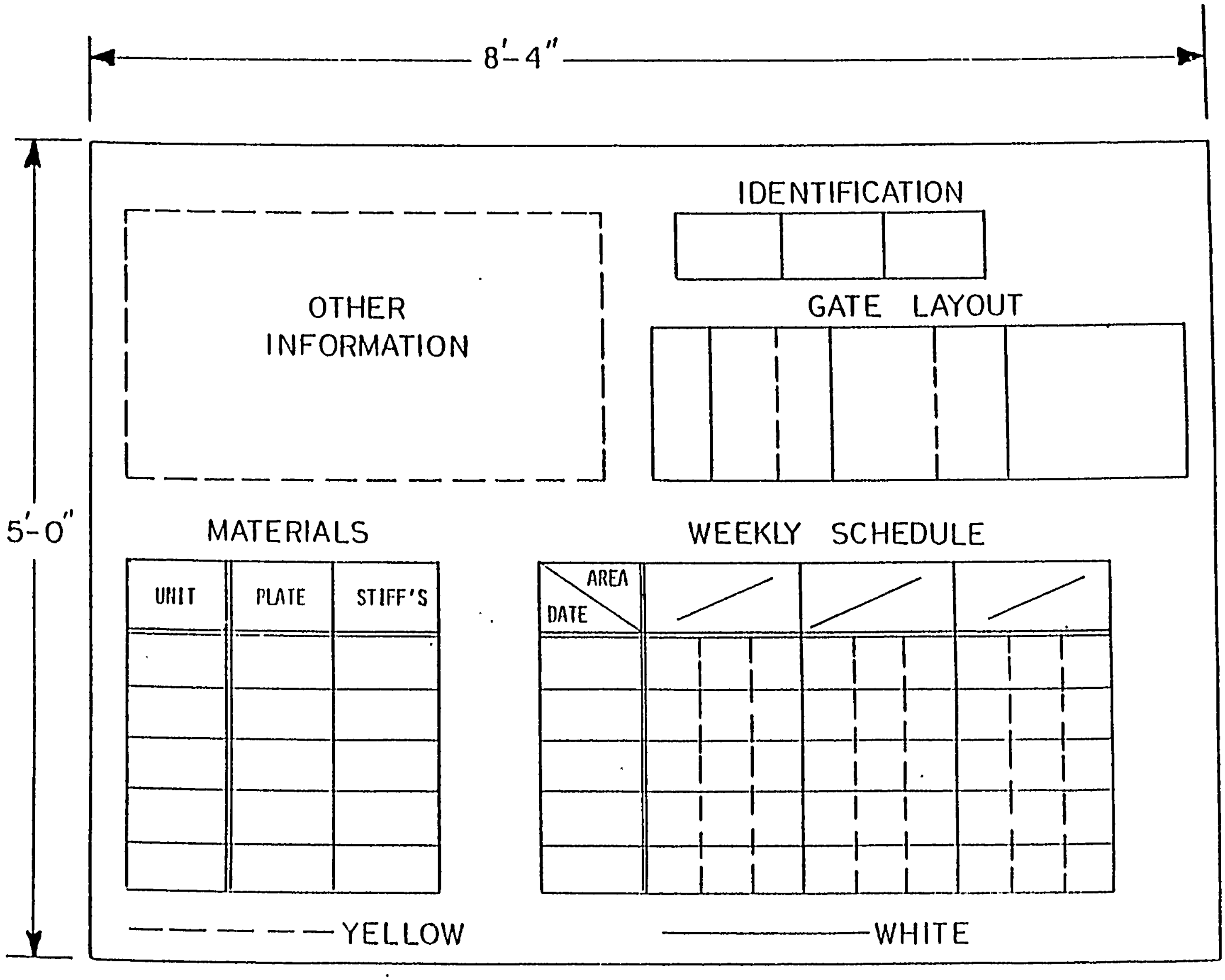



FIGURE 4-10 DESCRIPTION OF BLACKBOARD (SAMPLE)

## TABLE T4-1

## PROCESS STANDARD ELEMENTS

| ELEMENTS | EXPLANATION/EXAMPLES | INFLUENCING FACTORS |
|---|---|---|
| A. Material Handling | Raw materials, pieces, sub-assemblies, assembled units, etc. | 1. Method of transportation<br>2. Equipment options<br>3. Frequency<br>4. Distance |
| B. Marking | N/C, Flame Plancr, Manual at Fabrication, Assembly, Erection | 1. Method<br>2. Environment<br>3. Marking length |
| C. Cutting | N/C, Flame Planer, Manual at Fabrication, Assembly, Erection | 1. Method<br>2. Instrument<br>3. Environment<br>4. Plate thickness<br>5. Cutting length<br>6. Type of bevel |
| D. Bending | Plate, Structural, Bracket, Face Plate, etc. | 1. Method<br>2. Thickness<br>3. Amount of Curvatur |
| E. Fitting | At Fabrication, Assembly, Erection | 1. Method<br>2. Environment<br>3. Fitting length<br>4. Gap |
| F. Welding | At Fabrication, Assembly, Erection | 1. Method<br>2. Environment<br>3. Leg length<br>4. Material quality<br>5. Welding length |
| G. Finishing | At Fabrication, Assembly, Erection | 1. Method<br>2. Environment<br>3. No. of temp. pieces<br>4. Material quality |
| H. Painting | At Fabrication, Assembly, Erection | 1. Method<br>2. Environment<br>3. Area Painted<br>4. Type of Coating |

TABLE T4-2

CONTROL PARAMETERS

| SHOP | STAGE | WORKING | PARAMETER (IHI) | EFFICIENCY (IHI) | RECOMMENDED PARAMETER (LSCO) |
|---|---|---|---|---|---|
| FABRICATION | MARKING & CUTTING | EPM | NUMBER of plate | 0.5 H/PL | NUMBER |
| | | FLAME PLANER | " | 1.12 H/PL | ↓ |
| | | CURVATURE CUTTING | " | 2.85 H/PL | |
| | | N/C CUTTING | " | 4.66 H/PL | |
| | | SKELETON MEMBER CUTTING | " | 4.68 H/PL | |
| | | ANGLE CUTTING | " | 0.69 H/PC | |
| | | DECK HOUSE CUTTING | " | 6.22 H/PL | |
| | | SUB TOTAL | TONNAGE | 1.43 H/T | TONNAGE |
| | BENDING | ANGLE BENDING | NUMBER of piece | 1.5 H/P | NUMBER |
| | | PLATE BENDING | " of plate | 7.7 H/PL | ↓ |
| | | SMALL PIECE BENDING | " of piece | | |
| | SUB. ASSEM. | FITTING | W.L. | 6.2 M/H | NUMBER |
| | | WELDING | W.L. | 5.4 M/H | " |
| | | MATERIAL SORTING | TONNAGE | 0.5 H/T | TONNAGE |
| | | SUB TOTAL | TONNAGE | 8.95 H/T | " |
| | OTHERS | MATERIAL HANDLING | TONNAGE | 0.23 H/T | TONNAGE |
| | | SHOT BLASTING | NUMBER of plate | 0.48 T/PL | NUMBER |
| | | CRANE | | | |
| | | T.TYPE LONGL. | NUMBER of piece | 12.5 H/P | NUMBER |
| ASSEMBLY | EACH SHOP | PLATE JOINING | A.W.L. | 1.84 M/H | A.W.L. |
| | | FITTING | W.L. | 7.68 M/H | W.L. |
| | | WELDING | W.L. | 3.46 M/H | W.L. |
| | | FINISHING | W.L. | 20.09 M/H | W.L. |
| | | MATERIAL HANDLING | TONNAGE | 0.65 H/T | TONNAGE |
| ERECTION | PRE.ERE. SKIN. SKELETON | FITTING | W.L. | 2.77 M/H | W.L. |
| | | WELDING | W.L. | 0.91 M/H | W.L. |
| | | FINISHING | W.L. | 11.50 M/H | W.L. |
| OTHER JOB | | SCAFFOLDING | TONNAGE | | TONNAGE |
| | | CRANE | " | | ↓ |
| | | TRANSPORTATION | " | | |
| | | | | | |
| | | | | | |
| | | | | | |

in this table are the efficiency factors achieved at IHI and the parameters recommended for application at Levingston. These parameters are used to measure the performance factors that become the established cost standards.

CONTROL PARAMETERS

Table T4-2 reveals that IHI uses the following units of measurement as control parameters in their establishment standards:

Number of plates

Number of pieces

Tonnage

Welding Length (W.L.)

Automatic Welding Length (A.W.L.)

IHI seeks to use a parameter that relates to the time involved for processing of material as the primary consideration. Their objective is to use the simplest method of measurement without sacrificing accuracy or reliability of the data that is generated.

MEASUREMENT OF WELDING LENGTH

As mentioned earlier, there are two distinct methods utilized at IHI for the measurement of welding length. This length is determined by using either:

1) Conversion from unit weight

2) Measurement on drawings

The former method is a rough estimate based on weight and location of the piece. It is not sufficiently accurate to use in detail planning and scheduling of work within gates as performed by the Planning Department. The calculations in this method are made by the Engineering Department.

The latter method is more exact and useful in detail planning and control. It requires measurements from key plan drawings and requires a considerably greater investment in time. IHI estimates Levingston would expend approximately 100 to 120 hours to take the measurements on a vessel the size of the F-32, a 36,000 D.W.T. bulk carrier.

## ESTIMATING MANHOURS

### Hull Estimate

IHI uses combinations of techniques to estimate manhour requirements for an activity. The most common technique is use of historical data together with staff personnel experience to estimate manhours. On occasion, time study is used where historical data is not available, such as for a new process.

1. Coefficients - Rough Estimates

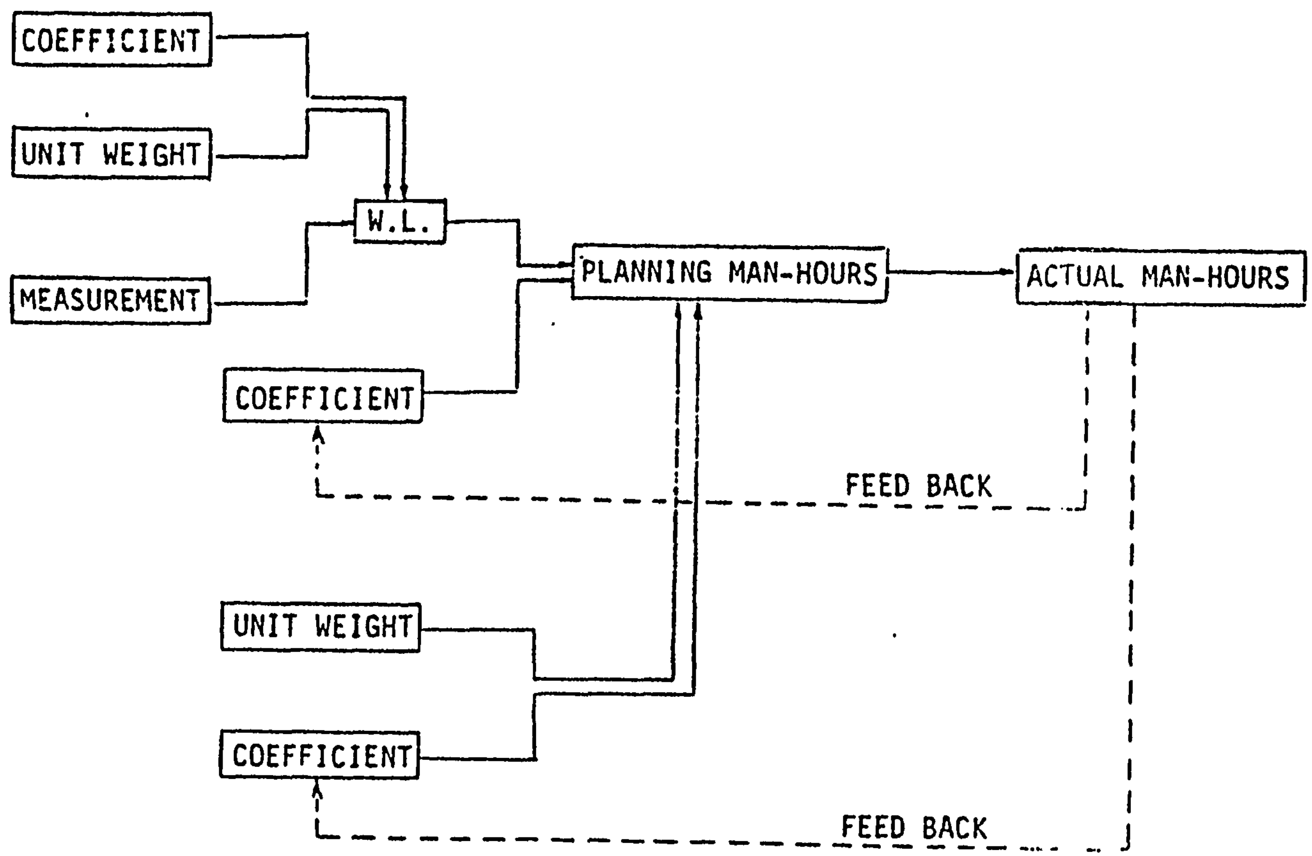
For planning purposes, IHI uses records of actual manhours to calculate difficulty factors, or "coefficients", that are used to estimate future manhour requirements. These coefficients are used to convert unit weights to welding lengths, which is extended by formula to determine manhours. The correlation between actual manhours, coefficient factors, unit weights, welding lengths and planning manhours is illustrated schematically in Figure 4-11.

IHI staff personnel recognize the variability of manhour requirements, depending on the existence or absence of various conditions. These are categorized into two groups:

a) Those dependent on the structure itself, such as:

- Classification of steel: mild steel vs. high strength steel

## ESTIMATION OF MAN-HOURS AT ASSEMBLY STAGE




ESTIMATION OF MANHOURS AT ASSEMBLY STAGE

FIGURE 4-11

- Type of floor: watertight vs. non-watertight bulkhead
- Shape of structure, e.g., flat, curved, cubic (three-dimensional odd-shaped units), width, length, etc.
- Number of small pieces involved
- Difficulty to achieve accuracy

b) Factors independent of the structure itself, such as:

- Weather
- Conditions for material preparation
- Accuracy achieved in fabrication, fitting, assembly, etc.
- Manpower leveling
- Equipment availability
- Condition of slab
- Production procedures
- Distribution of manpower

2. Coefficients - Detail Estimates

The estimating of manhours must also be performed in more detailed fashion. Where this is required, IHI engineers applied the same principles involved in the creation of coefficients on the charts of Figure 4-12 to develop a Table .of Manhours and Efficiency for each assembly unit on the bulker. This data is presented in Table T4-3, a sample showing representative units within the double bottom area.

## OUTFITTING

The on-module pre-outfitting assembly method practiced by IHI, with its standardized work procedures, lends itself readily to formulation of reliable cost standards. The manhours expended on a module assembly are captured and applied as standards and efficiency targets for installation of similar modules on subsequent ships. The data is continually updated and refined over periods of years, which results in increasingly accurate data for application as budgets and goals. The system of manhour goal calculations in the planning process is illustrated in Figure 4-13.

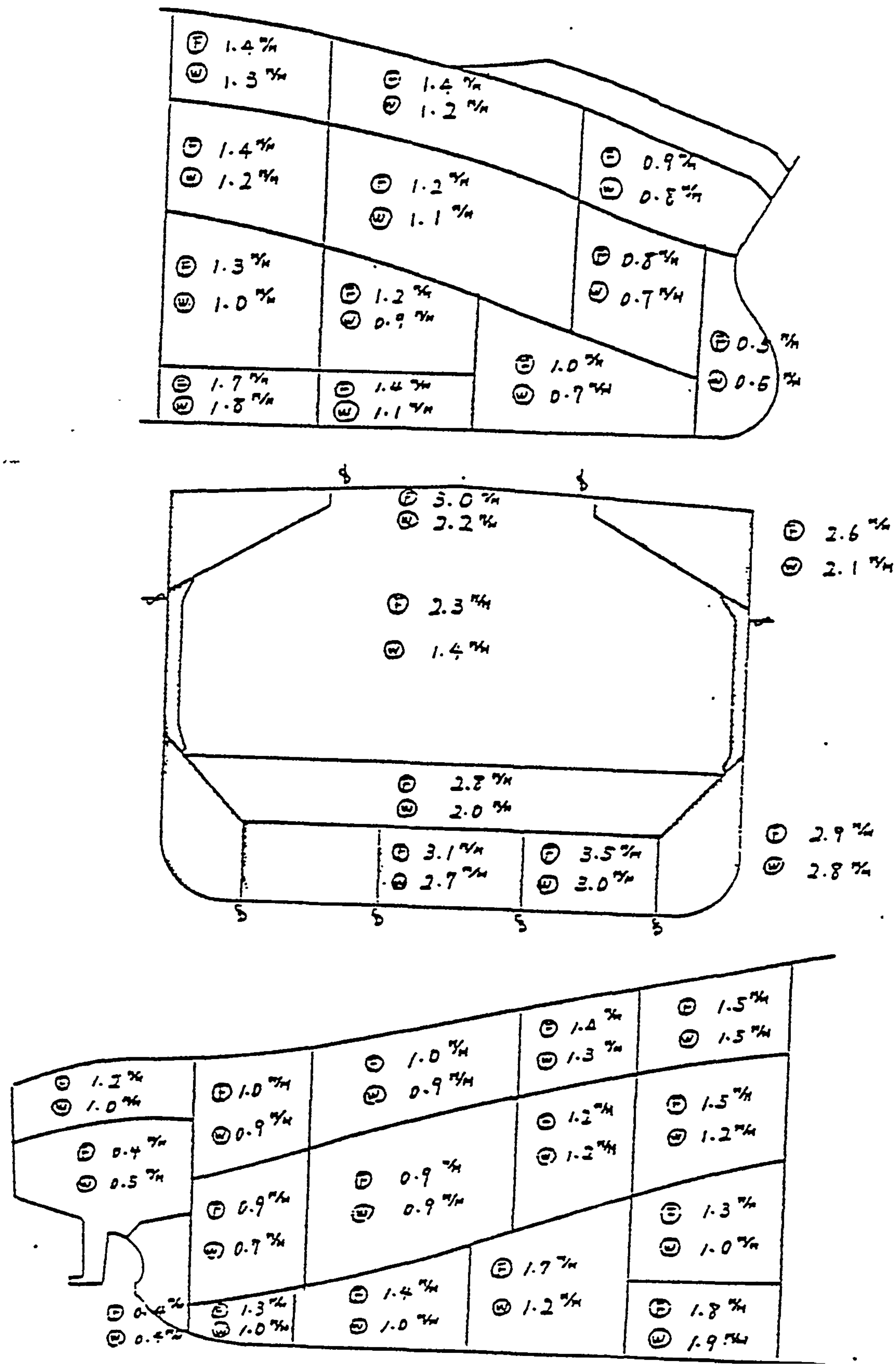
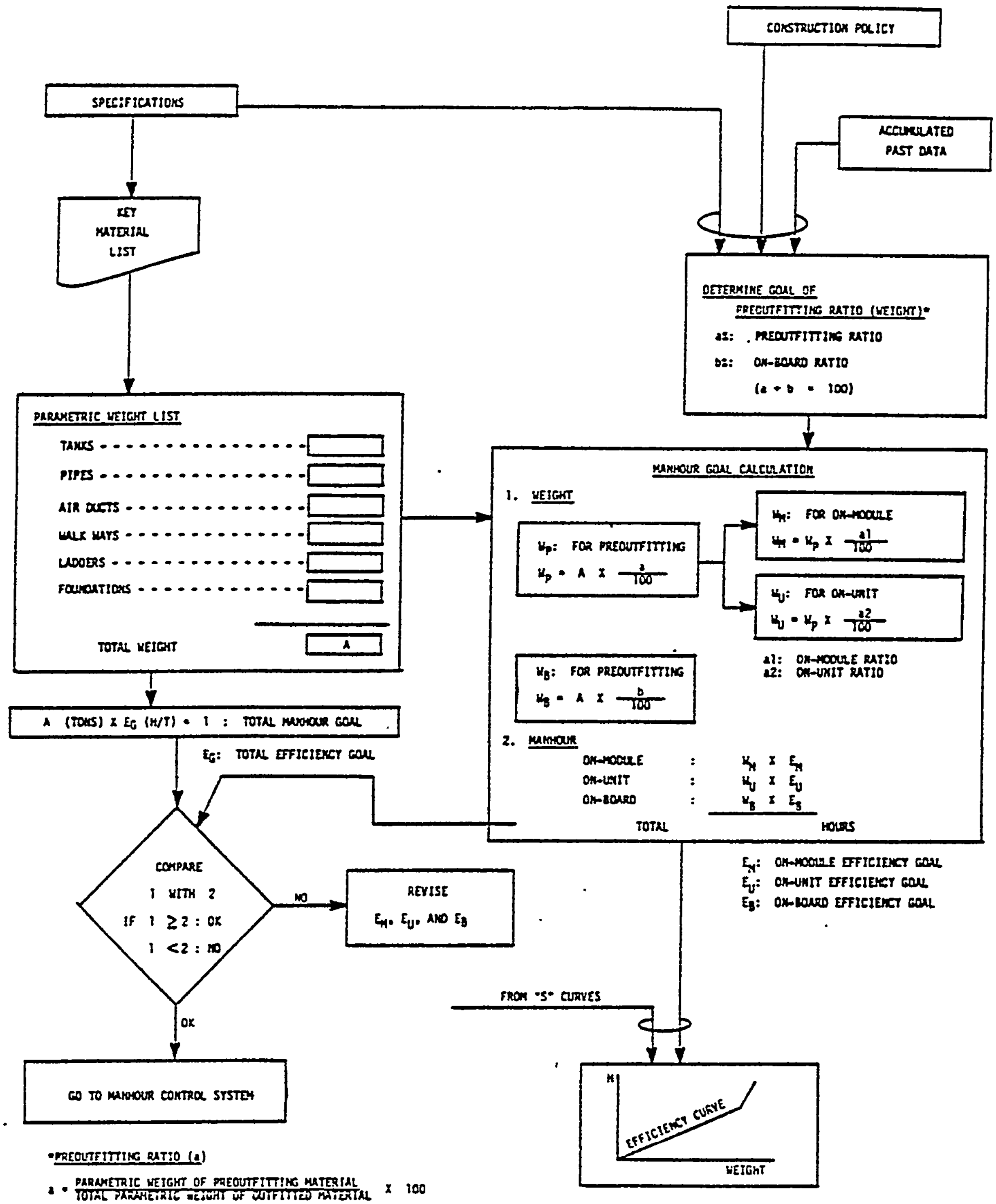



FIGURE 4-12 COEFFICIENT FOR EACH UNIT

## TABLE 4-3

## TABLE OF MANHOURS AND EFFICIENCY

| UNIT | WEIGHT | CONVERT RATIO | WELDING LENGTH | EFFICIENCY M/H | | MAN-HOURS | | EFFICIENCY H/T | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | FITTING | WELDING | FITTING | WELDING | FITTING | WELDING | TOT. |
| W.T. | Ton | T 9.4 | 578 M | 3.8 M/H | 3.1 M/H | 155 H | 190 H | | | |
| 101 | 61.52 | B 6.6 | 406 | 2.5 | 2.4 | 165 | 170 | | | |
| | | 16.0 | 984 | | | 320 | 360 | 5.2 H/T | 5.8 H/T | 11.0 |
| | | T 9.7 | 571 | 4.3 | 3.4 | 135 | 170 | | | |
| 111 | 58.91 | B 6.3 | 371 | 3.0 | 2.7 | 125 | 140 | | | |
| | | 16.0 | 942 | | | 260 | 310 | 4.4 | 5.3 | 9.7 |
| W.T. | | T 9.4 | 578 | 3.8 | 3.1 | 155 | 190 | | | |
| 121 | 61.44 | B 6.6 | 406 | 2.5 | 2.4 | 165 | 170 | | | |
| | | 16.0 | 984 | | | 320 | 360 | 5.2 | 5.8 | 11.0 |
| | | T 9.7 | 581 | 4.3 | 3.4 | 135 | 170 | | | |
| 131 | 59.95 | B 6.3 | 380 | 3.0 | 2.7 | 125 | 140 | | | |
| | | 16.0 | 961 | | | 260 | 310 | 4.4 | 5.3 | 9.7 |
| W.T. | | T 9.4 | 583 | 3.8 | 3.1 | 155 | 190 | | | |
| 141 | 61.99 | B 6.6 | 409 | 2.5 | 2.4 | 165 | 170 | | | |
| | | 16.0 | 992 | | | 320 | 360 | 5.2 | 5.8 | 11.0 |
| | | T 9.7 | 578 | 4.3 | 3.4 | 135 | 170 | | | |
| 151 | 59.58 | B 6.3 | 375 | 3.0 | 2.7 | 125 | 140 | | | |
| | | 16.0 | 953 | | | 250 | 310 | 4.4 | 5.3 | 9.7 |
| W.T. | | T 9.4 | 581 | 3.8 | 3.1 | 155 | 190 | | | |
| 161 | 61.86 | B 6.6 | 408 | 2.5 | 2.4 | 165 | 170 | | | |
| | | 16.0 | 989 | | | 320 | 360 | 5.2 | 5.8 | 11.0 |
| | | T 9.7 | 581 | 4.3 | 3.4 | 135 | 170 | | | |
| 171 | 59.95 | B 6.3 | 380 | 3.0 | 2.7 | 125 | 140 | | | |
| | | 16.0 | 961 | | | 260 | 310 | 4.4 | 5.3 | 9.7 |
| W.T. | A | T 8.1 | 315 | 4.3 | 3.4 | 75 | 95 | | | |
| 102 | 38.74 | B 6.9 | 268 | 3.0 | 2.7 | 90 | 100 | | | |
| | S | 15.0 | 583 | | | 165 | 195 | 4.3 | 5.0 | 9.3 |
| | A | T 8.1 | 312 | 4.6 | 3.6 | 70 | 90 | | | |
| 112 | 38.74 | B 6.8 | 265 | 3.2 | 2.9 | 85 | 95 | | | |
| | S | 15.0 | 577 | | | 155 | 185 | 4.0 | 4.8 | 8.8 |
| W.T. | A | T 8.1 | 315 | 4.3 | 3.4 | 75 | 95 | | | |
| 122 | 38.74 | B 6.9 | 268 | 3.0 | 2.7 | 90 | 100 | | | |
| | S | 15.0 | 583 | | | 165 | 195 | 4.3 | 5.0 | 9.3 |
| | | T 8.1 | 312 | 4.6 | 3.6 | 70 | 90 | | | |
| 132 | 38.74 | B 6.8 | 265 | 3.2 | 2.9 | 85 | 95 | | | |
| | | 15.0 | 577 | | | 155 | 185 | 4.0 | 4.8 | 8.8 |




**RECOMMENDED OUTFIT PLANNING BY PARAMETRIC WEIGHT**

FIGURE 4-13

## DEVELOPING STANDARD TIMES

It is apparent that the key to development of reliable process standards and cost standards for outfitting functions are dependent upon standardized, uniform working procedures and accurate manhour reporting, as was mentioned in the case of steel construction. This is accomplished by maintaining charts and graphs of actual productivity, by providing feedback on the accuracy of the projected standards, and by taking corrective action when discrepancies appear.

Examples of some cost standards recommended by IHI for Levingston on outfitting items are given in Table T4-4. This table exemplifies the cost standards that can be developed by using the experience of knowledgeable people combined with historical data. Figure 4-14 illustrates the use of cost standards in the determination of budgets for building a module.

## USES OF COST STANDARDS

The information obtained from process standards and cost standards may be used to construct charts on each unit, similar to the information as illustrated below:

| UNIT | SIZE | WEIGHT (TON) | WELD LENGTH | | MANHOUR | | | DAY | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AWL | MWL | PANEL | FIT | WELD | 1 | 2 | 3 | 4 | 5 | 6 |
| 101(T) | 40'x12' | 39.8 | 80' | 140' | 75H | 70H | 185H | 4W | 4W | 6W | 6W | 6W | 6W |
| (B) | 40'x12' | 50.4 | 80' | 105' | 75H | 55H | 160H | | | | 4W | 5W | |

Symbol Explanations:

| | |
|---|---|
| Fitting | MWL = Welding Length by Manual Process |
| Welding | AWL = Welding Length by Automatic Process |
| Panel Joining | T = Top Panel |
| WL = Welding Length | B = Bottom Panel |
| H = Hours (Manhours) | W = Workers (Fitters, Welders) |

TABLE T4-4

EXAMPLES - COST STANDARDS

| Work Description | Cost Standard |
|---|---|
| Slab layout | $5^H$ per module |
| Foundation setting | $3^H$ per piece |
| Machinery setting | $8^H$ per machinery |
| Prefabricated pipe fitting<br>(less than 60 lb)<br>(over 60 lb) | <br>$2^H$ per piece<br>$3^H$ per piece |
| Valves<br>(less than 60 lb)<br>(over 60 lb) | <br>$1.5^H$ per piece<br>$2.5^H$ per piece |
| ¦ | ¦ |

Craft by Craft

MLF X Cost Standard = Craft (1) Budget

MLF X Cost Standard = Craft (2) Budget

MLF X Cost Standard = Craft (3) Budget

SUM (1) + (2) + (3) = Total Budget by Module

BUDGET CALCULATION BY MODULE

FIGURE 4-14

At this point, final decisions are made concerning the assignment of units to designated gates. Consideration of such items as area of slab required (due to size of the unit) and amount of work required (for conversion from manhours to manpower) is involved. Workloads can then be leveled to accomplish jobs by priority and within gate capabilities.

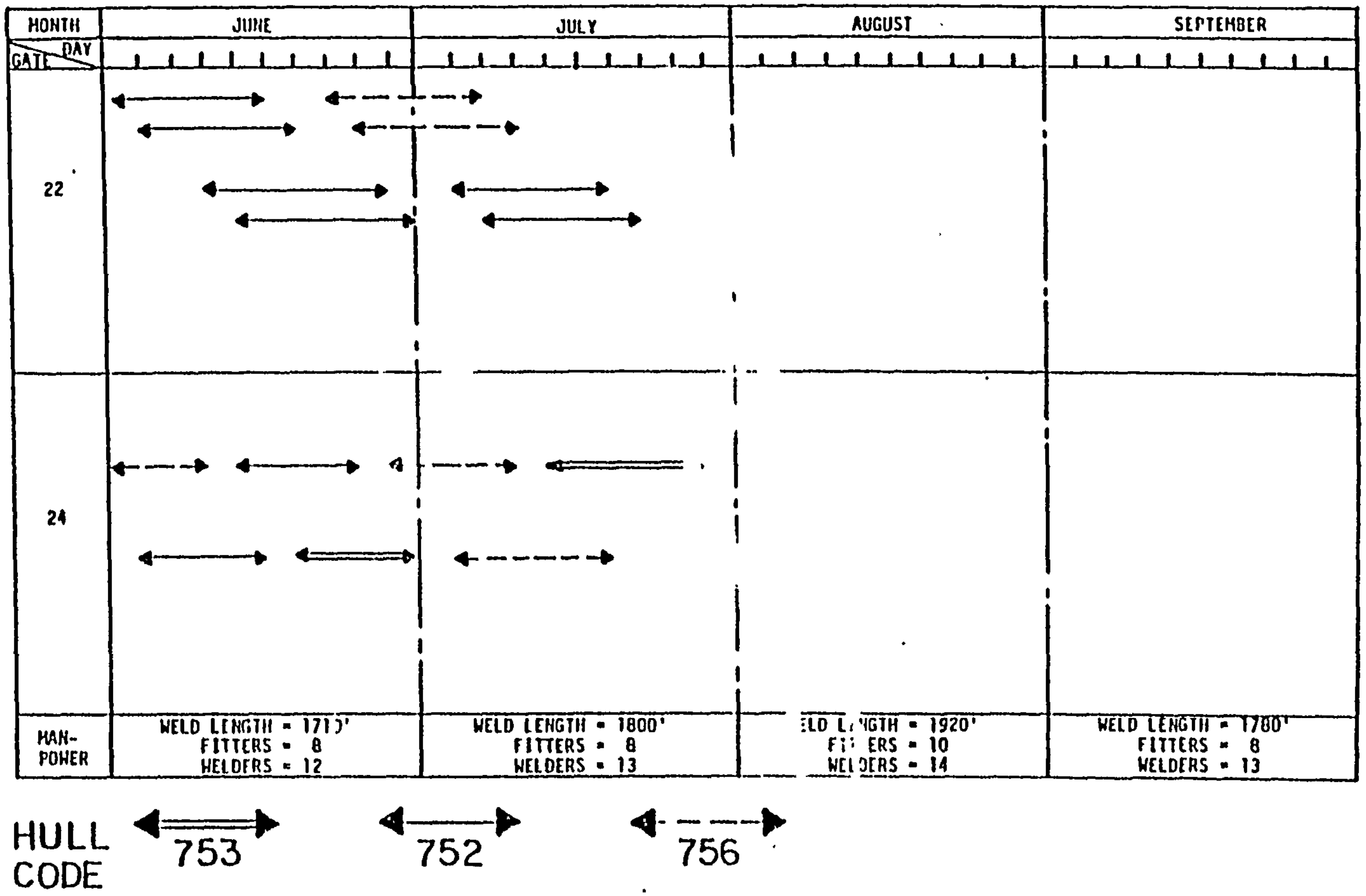
These data are converted to long-term schedules (See Example-Figure 4-15) and short-term schedules (See Example - Figure 4-16. The long-term schedule, covering a four-month period, accounts for production of each hull under construction. The short-term, thirty-day schedule, emphasizes the operations being performed on each unit at each gate.

A detail schedule can be issued for each assembly unit from this standard data. An example of such a schedule is shown as Figure 4-17. This schedule specifies the work performed to accomplish the fitting, welding, panel joining, and final assembly of the unit.

## SCHEDULING APPLICATIONS

Figure 4-18 presents the hierarchy of schedules developed from the primary master schedule. The Ship Construction Master Schedule is the top-level construction schedule for all work in a given yard. This schedule is prepared by the Production Control Group of the shipyard through an estimation of the required manhours per month based on the throughput rates established for the yard facilities and work force.

Master Schedules are next developed for Erection, Assembly and Outfitting stages for use as guidelines in developing the more detailed subschedules at each process stage.

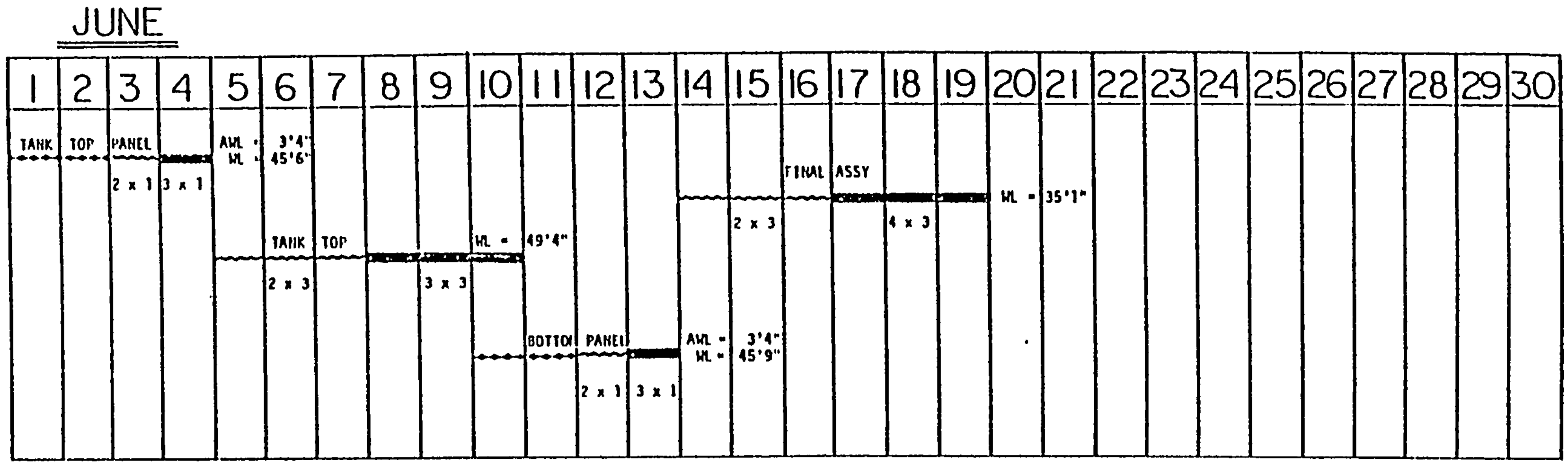



LONG TERM SCHEDULE (SAMPLE)

FIGURE 4-15

| GATE | UNIT | SIZE | WEIGHT | WELD LENGTH | | MANHOURS | | | JULY |
|---|---|---|---|---|---|---|---|---|---|
| | | | | AWL | MWL | FIT | WELD | 2 \| 3 \| 4 \| 5 \| 6 \| 9 \| 10 \| 11 \| 12 \| 13 \| 16 \| 17 \| 18 \| 19 \| 20 \| 23 \| 24 \| 25 \| 26 \| 27 \| 30 | 1 \| 2 \| 3 \| 4 |
| 22 | 101 | 40'x 15' | 50.6 tons | 80' | 170' | 75H | 180H | ←FIT→ ←WELD→ ←OUTFIT→ ←INSPECT→ ←PAINT→ | ←ERECT→ |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

FIGURE 4-16 SHORT TERM SCHEDULE (SAMPLE)




## LEGEND

PANEL JOINING

FITTING

WELDING

**TOTALS**

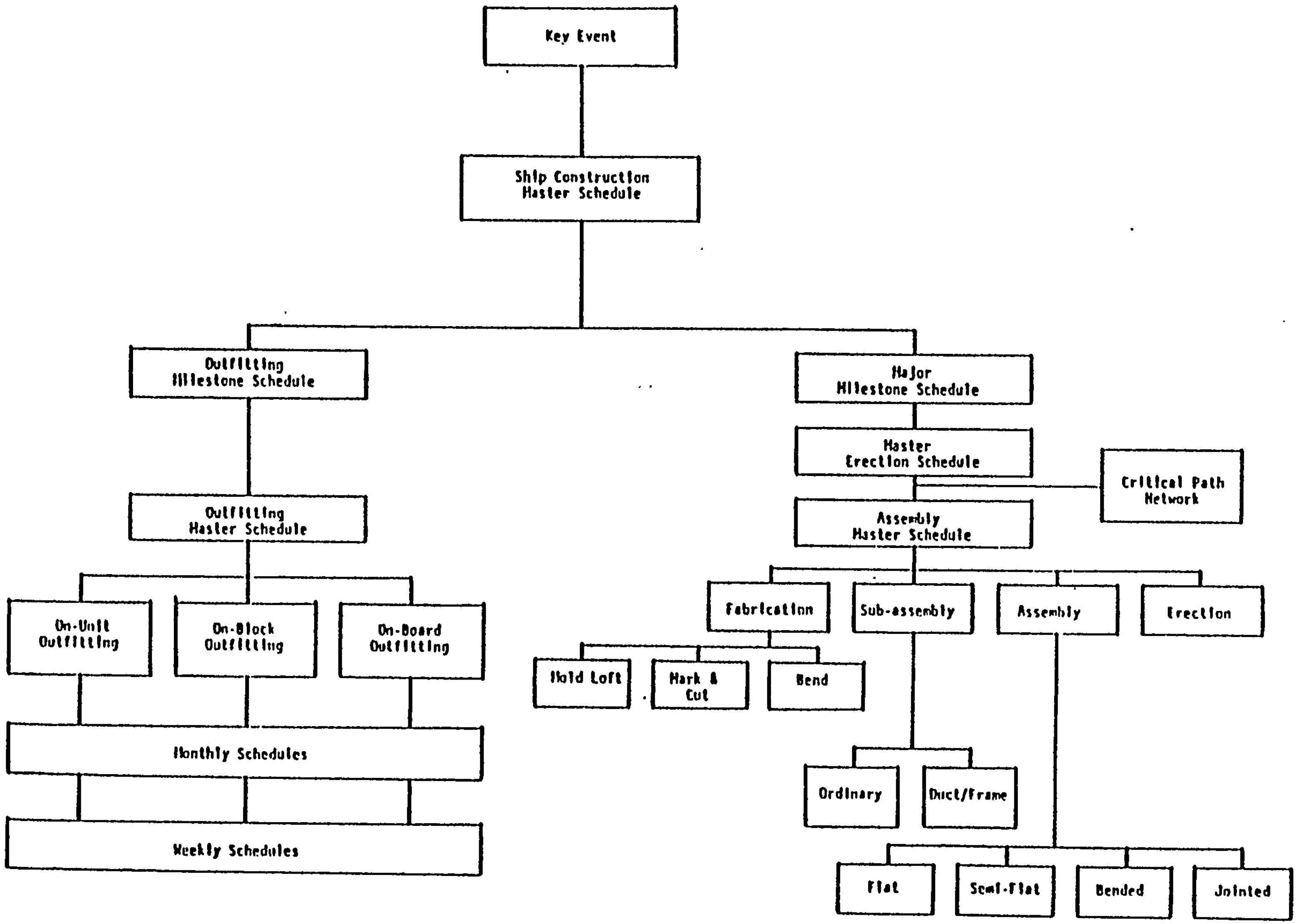
AWL (AUTOMATIC WELD LENGTH) = 6'8"
WL (MANUAL WELD LENGTH) = 175'10"
FITTING MANHOURS = 128 HR
FITTING EFFICIENCY = 1.4 FT/HR
WELDING MANHOURS = 218 HR
WELDING EFFICIENCY = 0.8 FT/HR

MANNING (EXAMPLE):

2 x 1 MEANS 2 WORKERS FOR 1 DAY

**DETAIL SCHEDULE (SAMPLE)**

**FIGURE 4-17**




## HIERARCHY OF SCHEDULES

FIGURE 4-18

The Erection Master Schedule is the first working schedule prepared. This schedule establishes the erection times for each unit in each zone of the ship.

The assembly Master Schedule is prepared to show the time requirements for each unit during the assembly process. Each type of unit is sorted by the type of fabrication process required for its production.

The number of required assembly days for the different types of units is a standard in the yards. This standard is shown in Figure 4-19. Also the calculation of manloading is standardized through the computation of weld deposit required on the various units.

## LEVINGSTON APPLICATIONS

The application of the IHI cost standards program first requires initiation of a corresponding system of process standards. A good process standards program provides a systematic approach for establishing documenting, and issuing standard work methods to the proper people. This is a necessary pre-requisite to implementation of an effective cost standards program through which the performance of standardized processes are measured and reported in terms of throughput rates and efficiency.

Particular emphasis is placed on the employment of process standardization techniques in the assembly functions, where written procedures and guidelines are issued for each typical unit of the hulls under construction.

IHI recommended the use of welding length as the control parameter for measuring performance standards, and subsequent calculation of cost standards.

At Levingston the flat panel line is a likely candidate for institution of standards based on measured welding lengths. This assembly shop performs

| PART | UNIT | ASSEMBLY | JOIN |
|---|---|---|---|
| FORE | Curved Skin | 8 | |
| | Semi-Flat | 7 | |
| | Pre-Ere. | | 15 - 20 |
| MID | Bottom | 7 | 7 - 10 |
| | Skin | 7 | 7 - 10 |
| | Bilge | 7 | 10 - 15 |
| | T. Bhd. | 6 | |
| | L. Bhd. | 6 | |
| | Deck | 6 | 10 |
| E/R | Engine Bed | 8 | 10 - 20 |
| | Curved Skin | 8 | |
| | Semi-Flat | 7 | |
| AFT. | Curved Skin | 8 | |
| | Semi-Flat | 7 | |
| | Pre-Ere. | | 15 - 20 |

REQUIRED ASSEMBLY DAYS STANDARD PER HULL STRUCTURAL TYPE

**FIGURE 4-19**

work of a routine, repetitive nature for which a direct relationship exists between manhours (of fitters and welders) and welding length.

Conversion from unit weight: This method proposed by IHI has merit as due to its simplistic formula calculation made from available data. However, the data requires verification through analysis of a shipyard's actual performance over a series of like vessels. Since Levingston has completed only the first F-32 type bulker at this time, the data has not been collected nor verified for application of this method. It is believed, however, that this method can have considerable value as a tool for calculating performance standards and cost standards.

The location of work influences its efficiency and productivity. At IHI, assembly is performed in covered shops under controlled conditions. At Levingston, this work is performed both in the shop (Flat Panel Line) and on slabs outside. The measured welding length method, therefore, is applicable to the Panel Line while conversion coefficients, less accurate but easier to obtain, are more appropriate to assembly work on slab.

In the Fabrication area, IHI recommended piece counts and tonnage as parameters for Levingston to use. Work orders issued at Levingston are written to correspond to the process gates through which a unit passes. Since manhours are charged against these work orders, Levingston plans to collect this data and use it as a basis for projecting efficiency on future work of a similar type. This is the method that has been employed successfully by the Japanese and is applicable to U. S. shipbuilding activities.

## CONCLUSION

The main objective of the calculation of performance standards is for use in projecting accurate plans and schedules. The data collection methods proposed by IHI are planned for implementation at Levingston when a sufficient data base has been compiled. Probably the single most important factor in providing a system of useful performance standards is assuring that accurate data is reported. The standards are only as reliable as the data upon which they are based. This depends on accurate reporting by supervision and validated calculations by people knowledgeable of the processes and methodology of technical analysis.

# SECTION 5

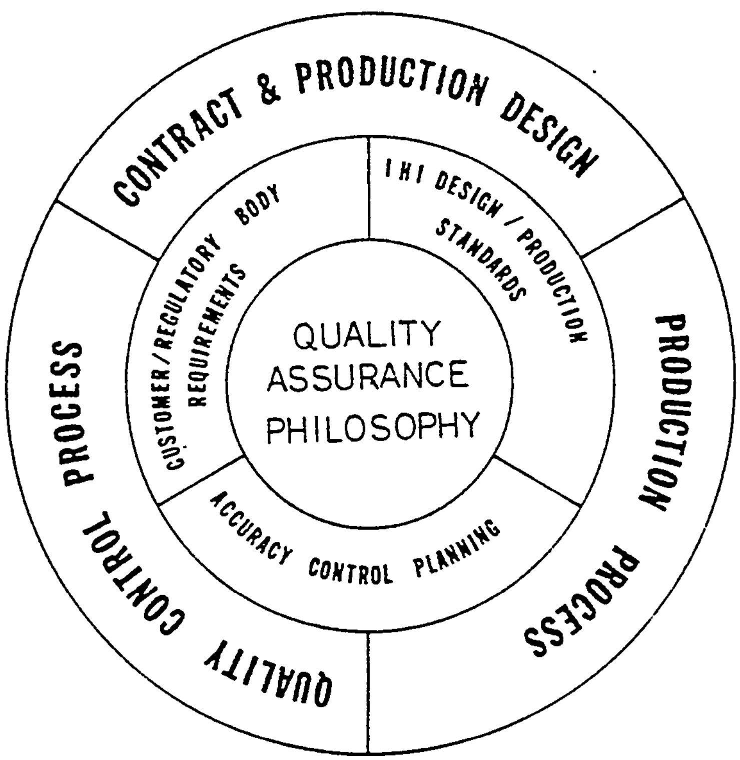
# QUALITY ASSURANCE

## SECTION 5

## QUALITY ASSURANCE

The IHI concept of Quality Assurance cannot be identified as a separate function or organization. Rather, it is a management, design and production philosophy found in continuous application at all levels of the organization.

The Quality Assurance function can best be described as an interactive system comprising the elements of regulatory body and customer specification requirements, IHI standards, and Accuracy Control requirements. These data form the basis for all design and production processes. Using this base, discrete organizational elements and methods and techniques were developed to apply and ensure adherence to these requirements in all design/production activities. In this system, Quality Assurance is an inherent aspect of the production process rather than a specifically defined organization whose charter is to "police" the end result of various production processes.



This system incorporates two discrete organizational functions: Accuracy Control and Quality Control. The first function, Accuracy-Control, is in reality a production planning and control process which establishes the basic scheme for ship production and, directly or indirectly, controls production methodology throughout ship design and construction.

The second function, Quality Control, is a management activity which supervises the overall inspection system, performs sample inspection and all nondestructive test (NDT) inspections, monitors production processes and techniques, evaluates quality control documentation, provides liaison with customers and regulatory agencies, and collaborates with Accuracy Control groups in perfecting production activities to obtain the highest possible accuracy and overall quality.

## ACCURACY CONTROL.

Accuracy Control is the underpinning of the IHI production system. This concept and its application has not only vastly improved the quality of IHI products but is a major factor in the outstanding productivity of IHI shipyards. The Accuracy Control system is not a single organization or function. Rather, it consists of four separate groups (one in design and one in each of three workshops) which are charged with a series of responsibilities.

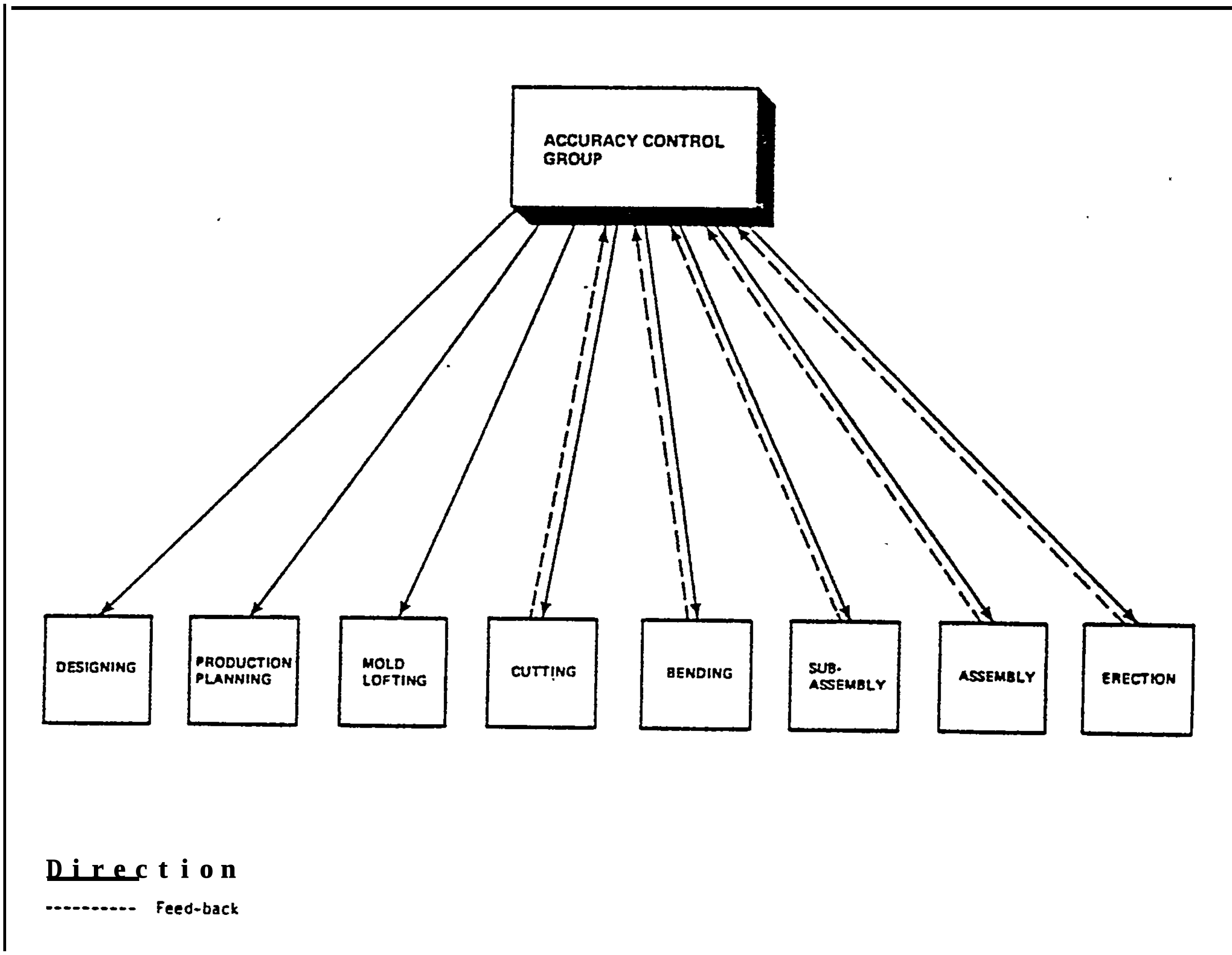
Accuracy Control begins in the shipyard immediately subsequent to completion of "Basic" design and prior to the start of detail design development. The initial activity is basic planning involving: ship work breakdown; determination of fabrication sequence and methods; establishment of critical dimensions, baselines and added material; determination of the erection sequence; and development of the plan for shipwrighting.

Subsequently, detailed "Check Sheets" are prepared specifying the measurements, dimension requirements, measuring equipment and frequency, for each item or assembly as it moves through the production process.

After this planning is completed, the Accuracy Control "Field Activity" is initiated where Accuracy Control personnel become active in the monitoring and measuring of plates, shapes, sub-assemblies and assemblies. The express objective of this planning and field activity is to maintain the highest accuracy possible in the major hull "blocks" or modules. The intent is to minimize to the greatest degree possible the work during the erection sequence. High accuracy in each hull module naturally means better fit, less re-work and greater efficiency during later production stages, particularly during erection.

Accuracy Control personnel are also concerned with the collection, analysis and feed-back of information to affected groups on quality, production processes and methods, work flow and sequencing. This activity not only assists in the correction of errors but also in the constant improvement of the IHI production system.

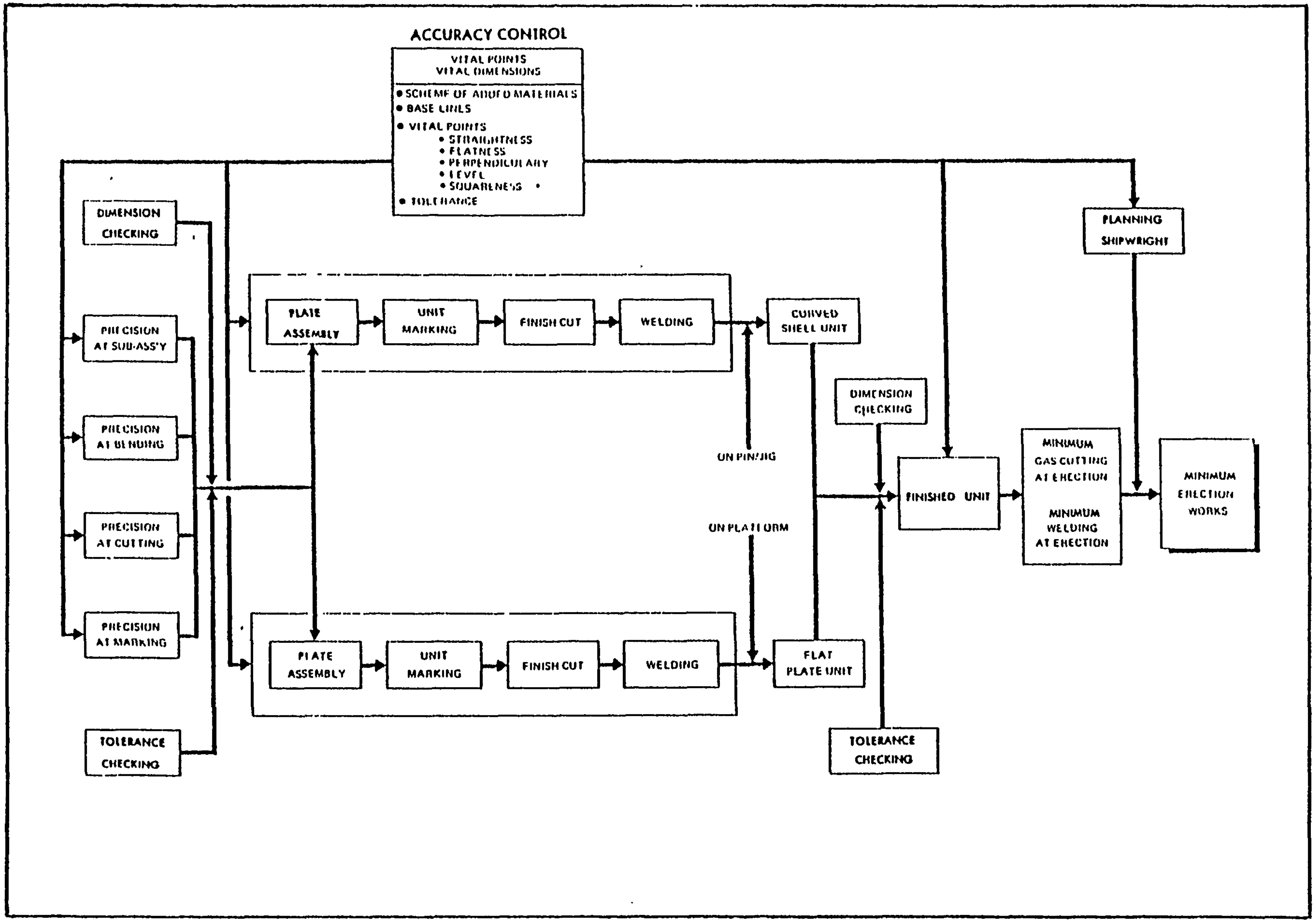
The Accuracy Control concept was the offspring of a management philosophy introduced by the President of IHI approximately 15 years ago. The application of the concept to the actual production process required many years of trial and error; but since its inception, Accuracy Control and its counterpart, Quality Control, have developed into the "standard" method governing ship construction.



The concept of Accuracy Control pervades all work and all levels of personnel with a concern for good workmanship and exactness. All work is expertly performed to exacting standards and, therefore, all successive work becomes easier and demands only the time required for the work planned for each work station. Poor workmanship, errors or material requiring clean-up is never passed from one work station to the next and only precise and error-free material flows through the building process, resulting in a sustained high level of productivity.

The development of the Accuracy Control concept within IHI has superseded and obviated any necessity for a "Quality Assurance" function. In fact, the combined Accuracy Control and Quality Control system is-Quality Assurance at IHI. The surprising aspect to this fact is that Accuracy Control is in reality a production planning and control process. Throughout the Accuracy Control activity, the intent is to thoroughly and properly plan each production process on each component, subassembly and assembly to obtain the highest possible accuracy. This activity occurs simultaneously with all other planning and is not separately identifiable from any other aspect of production planning.

It is interesting to note that in the IHI system, Accuracy Control is the method or means utilized not only to achieve high product quality but also the greatest productivity. These two objectives are achieved simultaneously and automatically. The "before-the-fact" planning accomplished by Accuracy Control establishes the basis for all subsequent planning and the "after-the-fact" measurement, data analysis and correction of methods, sequences and processes serve to perfect not only the planning but the production process itself. This continual improvement of planning data and


ACCURACY CONTROL
VITAL POINTS
VITAL DIMENSIONS
• SCHEME OF ADDED MATERIALS
• BASE LINES
• VITAL POINTS
• STRAIGHTNESS
• FLATNESS
• PERPENDICULARITY
• LEVEL
• SQUARENESS
• TOLERANCE
DIMENSION CHECKING
PRECISION AT SUB-ASS'Y
PRECISION AT BENDING
PRECISION AT CUTTING
PRECISION AT MARKING
TOLERANCE CHECKING
PLATE ASSEMBLY
UNIT MARKING
FINISH CUT
WELDING
CURVED SHELL UNIT
ON PIN/JIG
ON PLATFORM
PLATE ASSEMBLY
UNIT MARKING
FINISH CUT
WELDING
FLAT PLATE UNIT
DIMENSION CHECKING
TOLERANCE CHECKING
FINISHED UNIT
MINIMUM GAS CUTTING AT ERECTION
MINIMUM WELDING AT ERECTION
PLANNING SHIPWRIGHT
MINIMUM ERECTION WORKS

production processes results in a perpetual refinement of production techniques and a concomitant increase in productivity. Product quality in this scheme is almost a by-product of this continual improvement cycle.

The Accuracy Control concept is equally important as a tool for shipyard management, particularly middle or first-line managers. Both detail design and production planning are influenced by the Accuracy Control planning activity. Fabrication sequences and the techniques and methods to be used to achieve the highest accuracy and throughput are also directly influenced by Accuracy Control planning. Accuracy Control standards and Check Sheets prescribe the necessary workmanship requirements for each piece part and each successive unit. Prescribed measurements and measurement methods and instruments are the result of Accuracy Control study and planning. The erection sequence and the plan for shipwrighting, both resulting from Accuracy Control activity, detail the flow and work requirements for final ship construction and finishing.

Over the years these planning tasks have been perfected, along with a highly developed set of standards, to the point where all IHI managers, foremen, assistant foremen and workers are intimately familiar with them and rely exclusively on the information thus developed. Each manager, foreman and assistant foreman has precise and highly detailed guidance data for each work task assigned to him. All detailed planning and schedule data are based on the studies and the overall planning for fabrication and ship construction accomplished by Accuracy Control groups. As the work becomes further refined and scheduled, Accuracy Control concepts are translated to these lower levels of detail until finally, the entire ship construction process becomes a totally defined system of fabrication sequence and methods, of unit construction and outfitting, and of module erection and finishing.

This deductive planning method proceeds from the highest to the lowest levels of work all based on the objective of keeping the highest degree of accuracy possible at each stage of production.

With all of this planning and scheduling data precisely developed, managers, foremen and assistant foremen have little to do except to execute the work according to the plan. Their attention can be properly placed on the optimum positioning of material (within a work station), effective application of personnel, and on schedules and work quality. Unlike their American counterparts, they are able to place their emphasis on getting the work accomplished well and on schedule rather than on an exorbitant paper-work load, committee action, and "brush fires" usually related to errors in design, fabrication or assembly, or to "up-stream" or "down-stream" schedule slippages.

Managers at all levels know exactly what has to be done, when, and with what facilities and procedures. Only major exceptions cause any redirection of the established routine and these exceptions are generally not allowed to happen. Under this system, managers are free to accomplish their assigned work and to resolve problems among themselves at the lowest level practicable. Interference with their assigned work is a rarity mainly because interference is unnecessary and because all management and workers are aware and in support of the stringent schedules planned for each ship. These schedules are also a part of each person's concern with Accuracy and Quality Control. Obviously, only superb workmanship can be tolerated in a system geared to hour-by-hour schedules.

The effect of this system on people at all levels of the organization is far reaching. Although very little mention of Accuracy Control is made during visits to the IHI shipyards, it is apparent that the concept and its application have become indigenous to the work habits and the routine of the workforce. More obvious during these visits was the emphasis placed on Quality Control but only because discrete functions and organizations are easier to explain than underlying concepts.

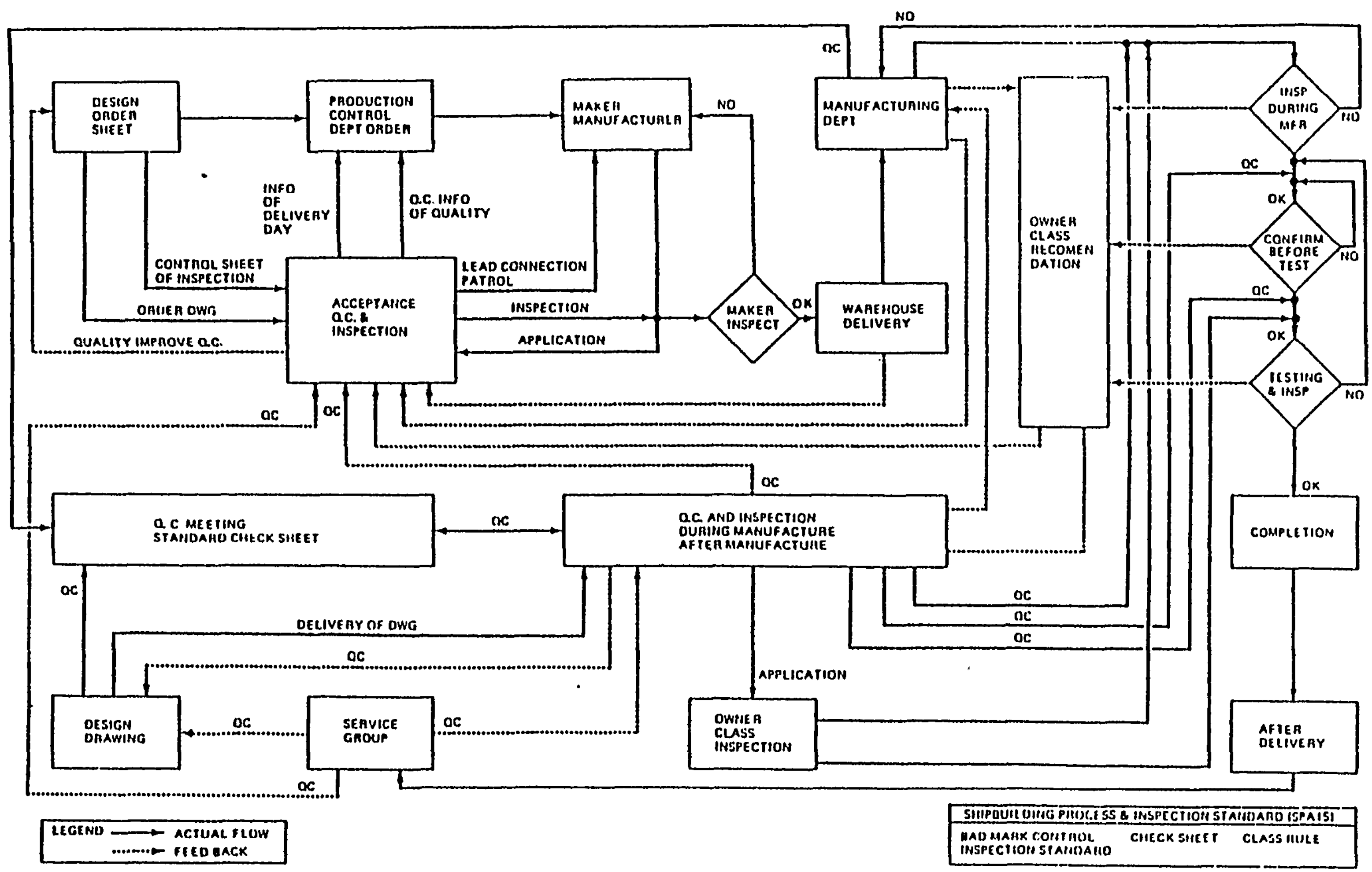
Accuracy Control within IHI is the guiding principle that provides all planning, design and production functions with the basis and the goal for their various activities. It is the guiding policy that gives form to the system and makes it comprehensible to the people who operate it.

## QUALITY CONTROL

The Quality Control function at IHI is a highly sophisticated inspection and data recording/reporting system. Although this function is organized in a single department, the Quality Control system extends throughout the yard and is integral to every workshop and trade. Most of the inspections are performed within the production department work groups by each worker, assistant foreman, and a member of the work group specifically designated to do nothing but check completed work. Each of these inspections are recorded on a Quality Control Check Sheet. Quality Control Department personnel sample inspect approximately five percent of all such work and customer/regulatory agency inspectors perform similar inspections at the assembly and ship erection stages. The IHI Quality Control system follows the "standard" Quality Control approach used by all Japanese shipyards.

Quality Control's role begins in the design process where quality requirements are input to the design engineers on an overall and a drawing-by-drawing basis. All drawings used for outside procurement are checked by Quality Control prior to release. Another aspect of Quality Control in the design process is in the development of quality specification requirements for purchased material and assistance in the development of Accuracy Control Check Sheets for the components and units built by the shipyard.

The responsibilities of Quality Control in the production process range throughout the typical functions of on-site vendor inspections, receiving inspection, in-process inspections, component and system testing, NDT inspections, and dock-site, builder and final acceptance trials. Throughout the process, Quality Control establishes the requirements, receives and records




GENERAL FLOW OF QUALITY CONTROL (IHI)

data (whether or not performed by a Quality Control inspector) and actively monitors the quality of workmanship and product at each stage of production.

The majority of inspection is performed by the workers at all stages of production. For example, warehousemen perform all material and component receiving inspection except for special components which are not routinely purchased. Welders perform a self-check of all of their work and when satisfied identify their work by affixing their signature. Another worker in each group (usually six to eight people) is assigned permanent responsibility for checking the quality of the work accomplished by all members of his group. This "checker" has no other duties. Each group's work is also inspected by the responsible assistant foreman prior to acceptance and movement of the piece or assembly under construction.

Because of the reliance placed on the individual worker, the group checkers and the assistant foremen, the Japanese Quality Control activity is more one of quality management. The Quality Control group establishes quality requirements for each product, educates and trains foremen, assistant foremen and workers in the accomplishment of the required quality, collects applicable data for analysis and for verification of work to quality standards and customer specifications , and generally monitors the production process to assure that established requirements are being met. In the performance of these duties,Quality Control representatives play an important part in virtually all aspects of design, production planning and the production methods utilized for ship fabrication and construction.

The most important procedure used in the IHI Quality Control system is the 3-point inspection system employed to assure the accuracy of the fabricated components and assemblies and the high quality of all weldments throughout the production process. In this regard, a single check sheet is used for each unit at each production stage which is signed by the assistant foreman, the group checker and finally by the Quality Control inspector on a number of various conditions which may exist on the work at each work station. This Check Sheet is used throughout the inspection process to document deficiencies and corrective action. All deficiencies are corrected by the worker making the error. The sheet is also used by assistant foremen to remedy continuing problems in cutting, fitting or welding by identifying persistent problems and either obtaining a correction in design or educating workers in proper techniques to prevent a recurrence.

During the processing of steel and outfitting, all work is identified either by worker's signature on welds or by means of work station personnel rosters. By this means, the group leader and checker/inspectors can identify specific individuals responsible for the work. A weighted factor (based on the importance of the work performed) is applied by the inspector to each error to achieve a summary "grade" or "bad mark" for each item inspected. The purpose of this system is related only to each individual's pride in his workmanship. No disciplinary action is taken as a result of "bad marks", it is simply a means of publicizing superior or poor work both to the individual worker and to his work group. These records are used to contin-ualy assess the performance of each group. Quality performance reports are posted in each work area.

One of the principal functions of the Quality Control activity is to assure the safety and well being of the individual workers. The Japanese recognize the importance of these personnel-oriented aspects of production. Their concern is based on the established fact that poor quality results from unsafe working conditions and/or unhappy workers. Therefore, Quality Control involves itself in all decisions concerning this type of personnel relations.

## CONCLUSION

Together, the Accuracy Control and Quality Control functions form a complete system for the detail planning and control of virtually every aspect of the production process. Because quality is the expressed objective of all shipyard practice, this system pervades all activities and levels of yard organization and has become an inherent part of the attitudes and work habits of the IHI workforce. Its many benefits are apparent in the constantly improving productivity rates of IHI yards, the established and smoothly working production system, management/worker relations, and in remarkably short building schedules and low costs

Levingston Shipbuilding has instituted a portion of the Accuracy Control concept in its yard in Orange, Texas. There are several possible alternatives to the institution of the entire Accuracy Control system: as a planning and production control function; as an extension of the Quality Assurance activity; and as a product improvement function. Levingston chose to experiment with the use of Accuracy Control in conjunction with its traditional Quality Assurance activity and has already obtained some significant benefit through the development and application of Accuracy Control Check Sheets in the measurement of components and assemblies during production of the modified Future 32 bulkers. This experiment has shown the potential benefits of even one portion of the Accuracy Control concept, however, it has made evident the difficulty of implementing a new and radically different methodology into a traditional American shipyard.

The concept 'of Accuracy Control is subtle but far-reaching in its effects. Although the emphasis is on quality, Accuracy Control is in reality the basis for all shipyard activity. Through this single mechanism, the basic planning is accomplished for all production activity. The execution of the-planning is then monitored (by all personnel) and constantly corrected and improved wherever possible. The attempt by all work groups to attain high accuracy in their completed work results in a finite reduction of re-work; movement of only good, high quality and clean work from one area to another; and the consequent ability to accurately plan and schedule each work station due to the absence of defects.

In spite of all of these desirable charateristics, the Accuracy Control concept is not easy to implement. The concept requires a somewhat different management philosophy and a radically different approach to typical American organization and practice. IHI has spent 15 years in its full development and is still improving and modifying its application. This difficulty initially arose from the fact that there was no defined system within which to implement the concept. Rather, the system had to be developed over many years.

Having an already developed system as guidance should allow the adoption of any or all of this concept into U.S. yards in a relatively easy manner. However, the Accuracy Control concept corresponds better with the Japanese culture, philosophy and life style and is in many ways contradictory to American concepts of organization and socio-economic structure. American relationships in management and labor, and of government in private enterprise, do not closely correspond to those of Japan. And, perhaps most importantly, the high mobility of the U.S. workforce militates against the perfection of any such system to the same degree enjoyed by the Japanese.

Certainly, a great deal of "tailoring" would be required to successfully adopt the Accuracy Control concept. But, even a "tailored" model of this sophisticated system could greatly benefit U.S. yards. The experiment currently being held at Levingston has proven that even a portion of the system can yield positive and beneficial results. Undoubtedly, a more thorough understanding and application of other parts or all of the system can improve both product quality and, ultimately, productivity.

# SECTION 6

# INDUSTRIAL RELATIONS

# EXECUTIVE SUMMARY

## GENERAL

In Levingston's study of the Industrial Relations functions currently in use in IHI it became clear that, although not identified as such, these functions comprise an integrated "Personnel System" which is a vital part of the production system of the IHI shipyards.

This "Personnel System" consists of many facets, each contributing to the overall personnel-orientation of. IHI and the Japanese shipbuilding industry. The Final Report of which this report is a summary examines each of these facets in detail and attempts to place all of the aspects of this "personnel system" into a logical context.

The elements of the "Personnel System" are as follows:

- Basic Organization Structure
- Operating Practices
- Pay Rates
- Benefits
- Personnel Welfare Systems
- Management/Labor Relations
- Training

## BASIC ORGANIZATION STRUCTURE

Ishikawajima-Harima Heavy Industries Co., Ltd., (IHI), is a large multi-company corporation involved in the manufacture of heavy industrial equipment, processing plants, and ships. The corporation maintains operations throughout the world although its headquarters and the majority of its manufacturing capability resides in Japan.

IHI operates six shipyards in addition to its numerous other companies. The shipyards of IHI are: Tokyo Shipbuilding and Crane Works; Yokohama No. 1 Works; Nagoya Works; Chita Works; Aioi Shipbuilding and Boiler Works; and Kure Shipbuilding and Fabricated Structure Works. The IHI shipyards are all organized and operated identically except for minor variations necessitated by geographical peculiarities and facility constraints.

Within IHI, the corporate office (Head Office) is responsible for all ship sales and for the establishment of the "Basic Design". Delivery schedules are also established by the Head Office after consultation with the yard selected for the construction program. Essentially, the Head Office controls the distribution of work to all of its six yards and is responsible for all marketing activities for these yards.

Many of the corporate groups contribute to the internal and external support of the shipyards and almost all of these groups maintain a direct interface with shipyard counterparts in their respective areas of responsibility.

Because of the similarities of the organization and operating practices of the IHI yards, it is possible to use the Aioi yard as a typical example for this discussion.

## Aioi Organization

The IHI Aioi District is organized into two major divisions: No. 1 Works - Boiler. Works and Shipbuilding; No. 2 Works - Foundry Works and Diesel Works.

IHI is licensed to build both Sulzer and Pielstick diesel engines and the No. 2 Works at Aioi is primarily concerned with these products. The Boiler Works which builds boilers for steam power plants both for land installations and for main engines for ships, is managed as part of the #l Works which is primarily devoted to ship construction and repair. The organizational structure of shipbuilding at Aioi is shown in Figure 6-l. Supplementing the IHI organization are approximately 35 subcontractors located immediately adjacent to the yard.

The Aioi District was recently reorganized (in 1978) to better reflect the several product areas and to clearly separate the functions and personnel of each area. The division into No. 1 and No. 2 works illustrates this product alignment. This division is specifically oriented around production functions with Sales and Engineering support provided by the IHI Head Office in Tokyo.

Also in this division of product lines was the distinction of primary "welding" activities as opposed to "machining" operations. The No. 1 Works (i.e. Shipbuilding and Boiler Works) is considered primarily as a welding operation, while the No. 2 Works (i.e. Foundry and Diesel Works) is considered a machining operation. This alignment of product line operations provides for a high degree of concentration of personnel, equipment, and facility resources in each product area.

Of the total IHI employment of 27,340 personnel in July 1979, the six IHI shipyards accounted for 11,272 or 41 percent of this total. Within Aioi Shipyard 3243 employees are dedicated to shipbuilding and ship repair activities, 2749 of them exclusively to new construction.

In the Aioi yard the average age of employees was 37 (in July 1979) and the average length of service with the shipyard was between

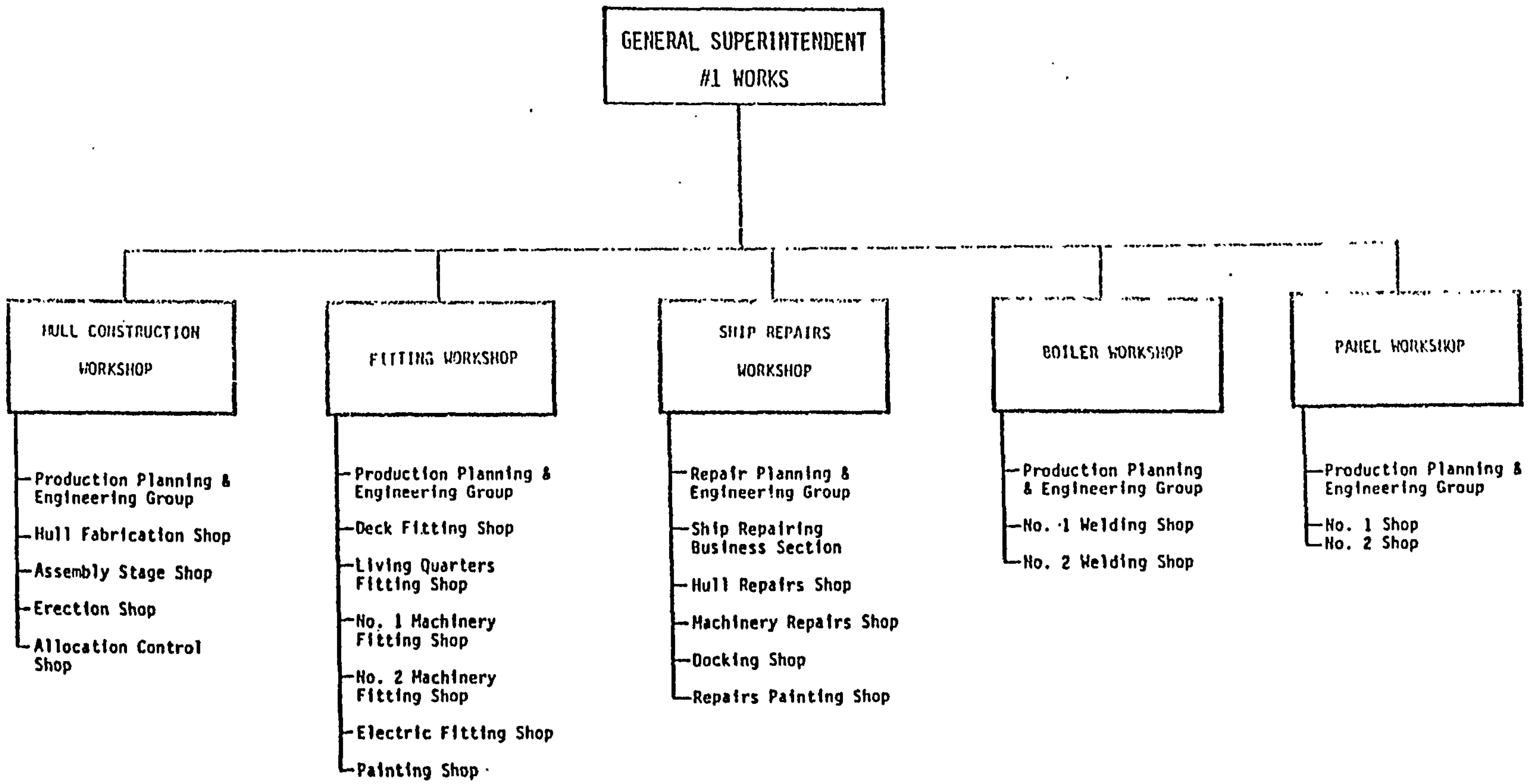



FIGURE 6-2

SHIPBUILDING/REPAIR ORGANIZATION

15 and 18 years. This maturity and tenure of the workforce accounts for much of the stability of the IHI production system. The skill level of individual workers is extremely high as is their familiarity with the planning and production system.

## Organization Analysis

The basic organization of an IHI shipyard (or the shipbuilding element of a district) is strictly oriented toward production (as opposed to marketing, administration, etc.) Because of the relationship of the yards to the IHI Head Office, the yards are relatively free from much of the general business activities concerned with the analysis and acquisition of new business, labor union activity, and administrative functions related to customer and government contacts and'contracts. Although the yards do maintain some elements of each of the above functions, these are much reduced in scope and practice compared to a self-contained U.S. shipyard.

The heart of the production system within the IHI yards is formed by the several "Workshops". Two of these workshops are dedicated to new ship construction: the Hull Construction Workshop and the Fitting Workshop. TWO other workshops, the Ship Repair Workshop and the Boiler Workshop, accomplish production work for products other than new ship construction. A fifth, the Panel Workshop, serves Hull Construction and Ship Repair.

Supporting these workshops are the Ships Design Department, the Material Department, the Production Control Department, the Quality Control Department and various administrative and Industrial Relations departments or groups.

The workshops are organized into "sections" which logically follow the ship construction process, beginning with Production Planning and Engineering, and followed by Fabrication, Assembly and Erection. Outfitting activities generally follow the same process breakdown with fitting effort occurring at the various stages of sub-assembly, assembly and erection.

Although the term "group" is used throughout the organization to indicate different functions and numbers of people, the "work group" is generally used to describe the units of production workers concerned with the fabrication, assembly or erection process. These groups range in size from 5 to 10 workers. Each group is headed by an Assistant Foreman; is concerned with one particular part of the production process; remains in one location; and performs the same type of work on each'component on which it works. One member of each group is assigned as a checker for all work processed by that group, Several groups report to a single Foreman who is in charge of a particular "work area" within a shop or assembly area.

Insofar as possible, work groups are structured with permanent personnel, locations, equipment and procedures. The group's function is held as stable as possible throughout a production run of ships. Also, every effort is made to provide a continuous flow of work to each group in order to realize maximum productivity.

The Japanese are particularly "group"-oriented. Individual achievement is not considered an acceptable goal in Japanese society. Rather, cooperativeness and successful group participation are the virtues most admired. Strong identification with the "work group" and with the company for which one works is common to most Japanese workers, and the feeling of "family" is likely to be as pronounced in these relationships as with a person's immediate family.

One of the most interesting aspects of the IHI shipyard organization is the placement of Staff Groups (Production Planning and Engineering Groups) in each of the production workshops and sections. These groups comprise a number of engineers who accomplish detailed planning, scheduling, trouble-shooting and coordination of the myriad activities in each workshop and section.

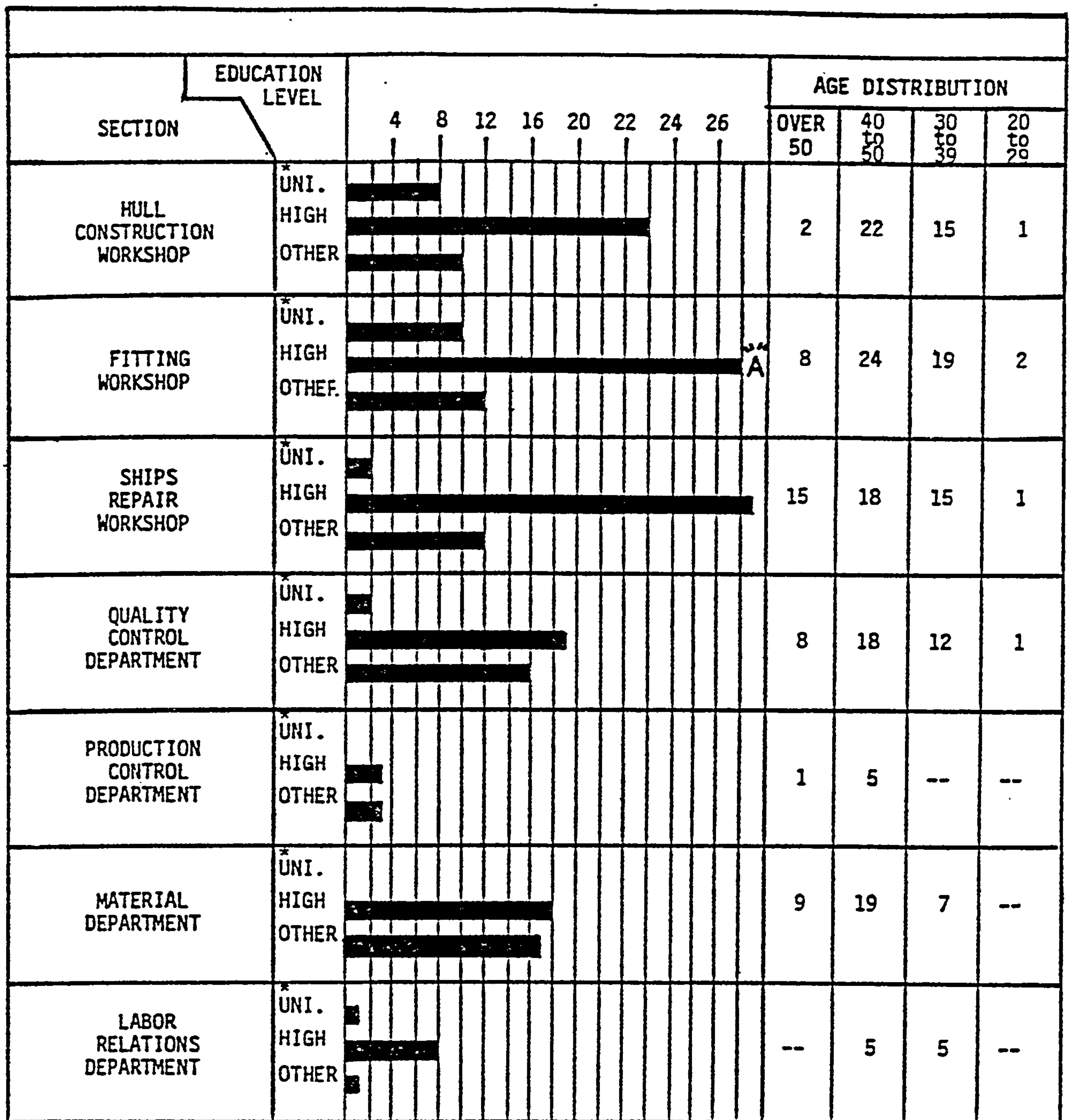
All Accuracy Control planning, workshop planning and sub-schedule development, lofting planning and scheduling, and data collection, analysis and feed-back are accomplished by these staff groups.

These groups work laterally across the organization and interface with each other throughout the development of planning and scheduling data and in all aspects of material flow, processing and integration.

Figure 6-2 shows the distribution of staff personnel in the various departments of the IHI Aioi Shipyard. As shown in the figure, staff personnel are also used in Quality Control, Production Control, Material Control, and the Labor Relations Department. These personnel (with the exception of the Labor Relations Department) accomplish the planning and scheduling required to support the workshops in their respective areas. These people work closely with the workshop Staff Groups to coordinate all necessary aspects of production.

## OPERATING PRACTICES

The IHI organization structure differs greatly from that of typical American firms primarily because it is more a description of




* UNI. - UNIVERSITY
HIGH - HIGH SCHOOL
OTHER - MIDDLE SCHOOL OR OTHER

"A" - 31 MEN

FIGURE 6-2

DISTRIBUTION OF STAFF FOR EACH SECTION

AIOI SHIPYARD

functions than one of reporting responsibility. The American concept of delimiting authority and responsibility via the organization chart is not understood in IHI nor generally throughout Japan.

Because of the group'orientation of all Japanese organizations, the individual tends to. participate fully in every activity where his knowledge and expertise have application. The best example of this lateral activity is that of the workshop staff groups which control the detailed fabrication, sub-assembly, assembly and erection or fitting work related to their workshop down to the smallest level of detail. These staff engineers are required to work with every aspect of design and production and virtually nothing is beyond the purview of their responsibility.

The entire organization is extremely informal and flexible. With the exception of detailed working plans and schedules, almost all communication is oral and written memoranda; and procedures are almost totally absent.

Not only is the concept of organization different from typical American firms but so is the management philosophy inherent in the organization. The basic management objective is to implement the policies set forth by the Chief Executive of IHI concerning the production of quality products and the provision of a personnel and labor management system which benefits all employees of the company.

The emphasis on personnel welfare is the chief factor in the organization and operation of Japanese shipyards. The Japanese have instituted a system of "welfare capitalism" which works reciprocally for the employee and the company. This relationship is not simply an economic arrangement between labor and management. Rather, it is based wholly on the concept that human dignity and welfare is the end objective of any system and that the corporation and the work performed therein is simply the means to achieve that objective.

## The Lifetime Contract

When a person is hired into IHI shipyards it is with the understanding that the employment is for the working life of the employee. A "lifetime" contract is established (although not in written form) between the company and the employee which assures employment for the employee's working career with IHI, beginning with the initial hiring and lasting until the age of retirement.

Under this arrangement the employee cannot be laid off or fired but may be relocated inside the corporation if work declines to a point where an individual company within the corporation cannot support its workforce.

This "lifetime" contract is an important aspect of the IHI personnel program and contributes substantially to the stability, tenure and productivity of the IHI workforce.

## Communications

Communications in IHI yards are largely informal and by U.S. standards totally lacking in formal documentation. Typically the Japanese conduct the majority of their business "face-to-face" in either individual conversations or in meetings of the interested parties. The Japanese pride themselves on their ability to communicate informally and this is coupled with a distinct desire for consensus decisions. The formal, written, factual and straight-forward memoranda and reports characteristic of American business are considered to be too harsh, too time-consuming, and too costly by the Japanese.

A significant aspect of this type of communication is that it encourages problem-solving in a direct manner without waiting for replies to memoranda or approvals of lengthy reports and plans. It also ensures that all personnel needing information and/or needing to participate in decisions are contacted, brought into the decision-making process and provided with ideas and recommendations from all participants. This process forces a decision and avoids the prolongation of problems which affect the production process. Additionally, this type of communication augments the "group" atmosphere of the shipyard, yielding an even greater sense of identity with, and participation in, the affairs of the company.

Productivity Improvement Programs

Several company-sponsored programs involve workers in continuing attempts to improve productivity in the IHI yards. In this regard conservation of both time and materials is considered a productivity improvement. Therefore, there is as much emphasis placed on the reduction of cost through conservation as for innovative production improvement ideas.

The three major improvement programs are the Suggestion/Award Program, the Zero Defects Program, and the Cost Reduction Program. Each of these programs receives a great deal of attention from both workers and management in the IHI yards. A friendly competition exists both within the yards between departments or work groups and also between shipyards in different locations.

## Employee Attitudes

Given the "Lifetime Contract", 'together with the personnel benefits and welfare programs, the Japanese workman enjoys security, identity, participation , and meaningful and satisfying employment in a working career of his choice.

Such circumstances would lead an American industrial manager to question the individual productivity of workers who have all of these benefits. However, the Japanese are some of the most industrious workers in the world.

Japanese workmen work across trades in almost every shop and area of the shipyard. In both hull and fitting areas, many IHI workers are trained to do both welding and fitting work and every employee is trained in cutting, welding and crane signaling.

IHI welders in shop sub-assembly areas normally operate five gravity-feed we ding machines simultaneously. Depending on a man's ability he may operate as many as ten on some sub-assembly work. Personnel assigned to N/C cutting or flame planing machines will manually trim or cut small pieces from plate as the plate moves through the machine. Personnel operating bending machines may also be alternately accomplishing flame bending of the material, individually or in a group where each of the personnel are capable of doing both jobs. Personnel in the fitting shops regularly perform tasks that in a U.S. shipyard would require several different crafts.

This diligent effort is characteristic of the Japanese workman and has its roots in Japanese culture and ethics. The attitudes of the Japanese regarding proper behavior, personal responsibility and integrity are manifest in their work habits, and in their respect for others in their work group and for the company for which they work. These attitudes are equally apparent throughout the management levels of the company and the IHI corporation. It is these attitudes which, perhaps more than any other single element, contribute to the stability and performance of the IHI shipyards.

EMPLOYEE PAY RATES

As of May 1979, Japan's Confederation of Shipbuilding and Engineering Unions Research Bureau published the following statistics on average pay rates for 204,800 shipyard employees:

1.) Average Age 35.8 Average Length of Service 13.7

2.) Average Basic Wage* (as of June 1978) - Monthly - $857.18
Hourly - $ 5.20

3.) Extra Pay for Overtime
(a) From 5:30 p.m. - 8:00 p.m. : 130% of hourly wage
(b) Before 9:00 a.m. and after 8:00 p.m., and weekends : 155 to 160% of hourly. wage

(Based on 15 O/T hours per month average for large shipyards in 1977) 4101.30 per month

4.) Bonus

(Based on average paid by the 7 largest shipyards in 1978) - $281.73 per month

5.) Welfare Benefits - $200.00 per month

6.) Monthly Summary

| Basic Wage | O/T Pay | Bonus | Welfare Benefits | Total |
|---|---|---|---|---|
| 8857.18 | 101.30 | 281.73 | 200 | $1,440.21 |

7.) Hourly Summary

| Basic Wage | O/T Pay | Bonus | Welfare Benefits | Total |
|---|---|---|---|---|
| $ 5.20 | 0.61 | 1.71 | 1.21 | $8.73 |

*Based on an 8 hour day and an exchange rate of 200 yen per U.S. $.

In all Japanese shipyards, cost-of-living increases are negotiated twice a year in addition to regular annual increases:

In the area of management and supervision, which are not represented by the union, several classifications exist ranking the salaries from Class 1 (highest) to Class 6 (lowest). These salaries are determined by the District General Manager and reviewed at least once a year for correspondence, with cost of living increases and new union settlements. Generally, management gets a rate of increase in salary and bonus commensurate with that obtained by the union.

A "Special Allowance" over and above the employee's basic pay is added on special occasions, for example, when an employee is married or upon the birth of a child. The rationale for this is that the employee has added responsibility and, therefore, deserves added consideration from the company. Special allowances are also provided upon the death of the employee, a member of his family and in the event of major injuries to him or his family.

## BENEFITS

### Vacations and Holidays

Vacation time for an IHI employee with from one to three years service is 14 days per year. From four to five years of service this time is raised to 17 days and from the sixth year until retirement 20 days vacation is standard. Vacation time can be carried over from year to year to a maximum of 40 days. No carry-over is allowed in excess of 40 days.

In addition to vacation time, each employee is given 18 paid holidays. Many of these are religious hol-idays occurring in the Spring and again in the Fall of each year. During these holidays the entire shipyard closes for a period of from one to two weeks.

Bonus Programs

in mid-Summer each year the union negotiates with the shipbuilding industry to determine the annual bonus to be paid each employee. The union considers that the annual bonus is part of the basic remuneration paid to shipyard personnel and therefore strives to maintain and improve this compensation during these negotiations.

According to a union report* the bonus for each employee amounted to $3,380.77** for the year 1978. Bonus figures for 1979 were not available.

This annual bonus does not, however, reflect all of the bonuses paid by the company to individual employees. Many of the bonuses paid are congratulatory or condolatory and involve paid absences as well as direct cash contributions.

Congratulatory bonuses are paid to employees upon getting married and upon the birth of children. Approximately $175 is the bonus upon getting married,accompanied by five days off with pay,and $25 is paid upon the birth of each child,with five days off with pay. These bonuses are in addition to the pay adjustments which also accompany these events.

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*Japan Confederation of Shipbuilding and Engineering Unions Research Bureau report dated May 1979.
**Based on a conversion rate of 200 yen per $.

Condolatory bonuses (or solatiums) are paid to employees upon the death of a wife ($150 with seven days paid leave) or child ($75 with seven days paid leave).

Upon the death of an employee, the wife is given $1,000 by the company and, in a job-related death, the Japanese equivalent of Worker's Compensation will contribute $80,000 in a lump sum plus 50 percent of her spouse's average monthly earnings for the last three months is paid monthly for the remainder of her life.

Also, inthe case of the death of an employee (on or off the job) a scholarship fund is established for each child of the deceased. For -each child attending school who is over the age of 18, the amount paid is $75 per month. For those under 18 years of age the amount is $50 per month.

A retirement allowance (bonus) is paid to all employees who have achieved 30 years of service with the company and have attained the age of 55. Although 58 is the normal retirement age, workers who meet the above conditions are treated as retirees and paid the retirement allowance. Upon reaching the retirement age of 58, workers normally have the option of remaining with the company for an additional two years or retiring, depending on the state of their health. However, because of the cut-back in production in recent years most retirees have voluntarily retired upon reaching 58 or even earlier at age 55.

The retirement bonus is based on the education and position of the employee in the company at retirement. The lowest bonus paid would be to a technical worker who had graduated from a junior high school and had spent 30 years as a worker. In this case (in 1978) the retirement bonus was approximately $42,000. In the case of an engineer with a university degree this bonus would be approximately $100,000. Upper management would get proportionately more.

## Insurance

Health insurance programs are in operation in all IHI companies. This insurance typically covers hospitalization, out-patient expense and the expense of drugs and medications. These programs are not unlike those provided by American firms except that generally the benefits are more all-encompassing and the company pays the total premium.

## Housing and Dormitories

When an employee is first hired and has to relocate his family to the shipyard site, temporary housing may be provided until he can locate a residence. Generally this temporary housing is provided by the company free-of-charge for a period of 30 days. However, in some cases, permanent housing may be provided within the confines of the shipyard for foremen, section managers and managers. In this case, a nominal rent is charged.

Many new employees are bachelors when they first go to work for the shipyards. Because of the low beginning pay offered these new employees,the company also offers dormitory quarters at a very low rate (approximately $4.00 per day).

When an employee marries and can no longer use dormitory facilities, the company offers low-interest loans to assist the employee in the purchase of a home.

## Cafeterias and Commissaries

At all IHI shipyards a company cafeteria is operated for employees. Employees living on-site (in company housing or dormitories) can obtain all meals at these cafeterias. Personnel living off-site generally eat lunch at these facilities.

The cost of these cafeterias is shared by the company and the employees, in that the cost of the facility, of food preparation and of handling service is borne by the company, whereas the cost of the food itself is borne by the employees. This sharing of costs provides for low cost meals (approximately 50.60 for lunch) for all employees. A similar arrangement is provided for the management staff in separate facilities ad,iacent to their work areas.

At some yards small commissaries or co-ops are provided for em-. ployees. Usually these commissaries carry a modicum of foodstuffs and typical drug store items but may also carry small appliances and tools. Items sold in these commissaries or co-ops are usually priced well below those of retail merchants in the city.

## Travel Allowances

The cost of commutation tickets (usually by train) is totally. paid by the company for employees requiring such travel. Also, for employees who have to drive personal cars to work, travel allowances are paid according to the distance of travel required.

## Work Clothing

All employees in the shipyard are issued uniforms, safety boots, gloves and safety helmets by the company. This clothing is replaced by the company when it is sufficiently worn. Proper clothing is considered essential to the safety program and, therefore, has been standardized throughout the shipyards.

## Commendation for Long Service

Prizes (usually monetary) are awarded to employees who have served 20 years with the company. Successive awards are made every five years thereafter.

Upon reaching retirement age, employees and their wives are given a four-day trip by the company with all expenses paid.

## PERSONNEL WELFARE PROGRAMS

In addition to the many employee benefit programs in IHI, several other on-going activities pertain to the safety and quality of life of the IHI workers. These established programs are augmented by management/union negotiations on personnel welfare occurring in the fall of each year.

Personnel welfare embraces all aspects of safety, environment, recreational facilities, medical/dental care, and employee relocation. These elements of employment are considered equal in importance to pay rates and benefits by the individual employees and their union.

## Safety and Sanitation

Safety is of paramount importance in the shipyards of IHI. Intensive programs are continuously conducted to improve the safety aspects of ship construction.

Each yard maintains a full-time Safety Group which is in charge of the safety program and its implementation in the yard. The Safety

Group is divided into various sections: the Staff, which is responsible for formulation of safety policy and instructions; a control committee for subcontractor safety requirements; and a safety inspection group which performs daily inspections of shipyard activities, corrects unsafe conditions and operating practices and reports back to the staff groups on inadequate safety measures.

This emphasis on safety has resulted in a very low incidence of job-related injury. For example, in Aioi a total of 9 lost-time injuries were reported in 1978, 5 in 1977, 11 in 1976, and 9 in 1975. The number of deaths in the yard since 1974 totals three, two of which were of subcontractor personnel.

Sanitation is also a major element of the Safety Program in the shipyards. This activity is concerned with all shipyard environmental conditions such as air and water pollution, noise, the working environment in shops, assembly and erection areas, and the environmental effects of the shipyard on the community. In these activities, stringent control of pollution (air, water, and noise) is accomplished and shipyard working conditions are constantly improved. Under the safety and sanitation programs, shop conditions have been improved by various types of ventilation systems, the enforced use of proper respiratory protection equipment, improved lighting, the removal of high noise equipment (e.g. chipping hammers) and through strict enforcement of open aisleways and transport lanes.

Abrasive blasting, acid cleaning, and primary painting operations are confined to enclosed buildings and the processes automated to the highest degree possible. In assembly and erection areas, sophisticated scaffolding with safety rails and netting are used to provide easy and safe access to all parts of the large assemblies and of the ship. AS part of each employee's uniform, a safety rope is worn attached to a web belt for use whenever working in high places. These and many other devices and procedures are an inherent part of the production process and the continuous safety and sanitation improvement programs are constantly seeking new means for improving the working environment of the shipyard and for preserving the living environment of the community.

Separate from the safety and sanitation aspects of personnel welfare is the attempt to make each yard a pleasant working environment. This activity concerns the appearance and habitability of the shipyard and its desirability as a place to work.

The primary element of concern is cleanness of the facility.and the orderly arrangement of all of the various shops, platen areas, storage areas, etc. This orderliness is supplemented by green areas (i.e. small areas of lawn, trees, various plants), fish ponds and smoking areas, wherever possible.

Another significant feature contributing to shipyard appearance is the use of pallets for the collection, storage and movement of materials. All small fabricated parts and outfitting materials are segregated on pallets of various types and sizes, as well as many loose working tools and equipment such as crane cables and alignment or attachment jigs. These pallets are usually stored in warehouses or immediately adjacent to the appropriate working area in designated locations. This use of pallets contributes greatly to facility appearance and is an essential part of the material control process.

Control of scrap is another important aspect of facility cleanness. Scrap containers are situated in proximity to every operation and employees are charged with the responsibility for maintaining their work areas in a clean and safe condition at all times. Scrap is promptly removed after each cutting operation and slag from burning and welding operations is either collected in pre-positioned containers beneath work tables or automatically dumped by a slag-collecting plate conveyor in some locations.

Several practices are used by the IHI yards for periodic yard clean-up by employees. The IHI Kure shipyard stops work for 30 minutes at the end of each day to allow employees to thoroughly clean their work areas. In Aioi workers clean-up throughout the day at intervals where there is a break in the work flow or immediately after each operation which yields scrap or other residual material requiring clean-up.

Employee Facilities

Throughout the IHI shipyards, numerous facilities are provided for the employees ranging from housing to recreational areas. There is a determined effort to provide for the health and morale of the IHI workforce which embraces aspects of diet, exercise and convenience.

In addition to housing and cafeterias, recreational areas and facilities are provided by the company such as swimming pools, baseball diamonds, club houses, and the like. Also, many areas are designated in the yard (on streets) for employee activities during lunch time and after work. These areas are for use by the employees for games such as tennis (without the net), volleyball, or any other team activity that can be accommodated in the prescribed area.

## Medical/Dental Care

Each IHI shipyard has at least one full-time doctor and one full-time dentist on duty at all times. Medical care is provided for all workers as required, whether for job-related injuries or not. Provision of medical and dental service in the yard naturally tends to decrease lost time due to employees having to .seek outside medical/dental attention. It is also a significant benefit for employees as the service is cost-free for the employees.

## MANAGEMENT/LABOR RELATIONS

Japan has achieved what appears to be an almost ideal marriage of labor and management objectives which are mutually beneficial to both workers and the company.

Both management and workers point with pride to the fact that they are "partners", in business to sustain and improve the shipbuilding industry, the particular enterprise, and the welfare of all employees.

The underlying philosophy for this approach lies in the Japanese respect for human dignity and for the right of every individual to an acceptable livelihood and security. Seen from this viewpoint, the welfare of employees in all industries is the ultimate objective of business. This, of course, is regarded by most Americans as purest "socialism" and, in fact, Japan is far more socialistic in this practice than the U.S. However, because of the respect for private enterprise and for competition among the large industries, it is perhaps more "welfare capitalism" than "socialism".

All employees (except managers, staff and engineering personnel) belong to the union, not because of any "closed shop" rules *or* attitudes, but because it is generally considered unfair (and consequently a "disgrace") to be covered by the union contract and not belong to and support the union. Because almost all employees belong to the one Shipbuilding Union which covers almost the whole shipbuilding industry, there is no fragmentation between yard workers. Unlike U.S. yards, where each craft is represented by a different union, Japanese workers identify with a single entity representing all crafts. This tends to consolidate the union memebers and alleviates much of the competition and disagreement between local unions. This situation also encourages unity rather than separatism within the crafts themselves. Japanese workers identify with and show allegiance to the shipbuilding industry, the shipbuilding union and to the company for which they work. This is in contrast to U.S. workers who identify first with their particular craft, the local craft union, the larger national union and then to the company.

The Japan Confederation of Shipbuilding and Engineering Workers Union (Japan ZOSEN JUKI ROREN) is the major shipbuilding industry union in Japan. This union represents the workers of all major shipbuilding companies and negotiates at the national level with the collective body of companies owning shipyards throughout the country.

The Shipbuilding Union is tied into the Japanese Confederation of Labor, which oversees all union movements in the country and attempts to uniformly develop each sector of union involvement in the society.

Each year three major negotiations are held by the union and the companies involved in shipbuilding. These negotiations are referred to as the yearly '*struggles" and are programmed to accomplish definite objectives at each meeting. The Spring Struggle concerns wages and some fringe benefits; the Sumner Struggle is primarily concerned with the establishment of the yearly bonus (which is considered by the Union to be a part of the basic wage of each worker); and the Fall Struggle is concerned with yearly labor agreements, improvement of working conditions, and personnel welfare programs. Cost of living increases are negotiated twice a year,in. the Spring and again in the Summer. Many of these negotiations are conducted through a unified "struggle" of all union-organized industries. Many of the benefits discussed elsewhere in.this,report 'are therefore universal throughout Japan.

On the local company.level, union activities are largely carried out by the company's Labor Relations Department. This department is charged with the responsibility to administer the union contracts within the yard and to see ,that all requirements of the contract are satisfied by the company.

## TRAINING

As in all other.aspects of the shipyard, training. in IHI is -highly systematized with thoroughly developed curricula and courses for new employees and for .further education and refresher courses for those with longer tenure with the company.

Since the curtailment of hiring brought about by the shipbuilding recession in Japan, almost all'apprentice programs have been suspended. However, continuing education of the workforce is considered a vital part of the shipyard process and is inherent in every new shipbuilding program.

All new employees are thoroughly trained or indoctrinated into their jobs by means of several structured curricula. New employees are ranked according to the level of education completed and are required to take whichever training program parallels their formal education and the job for which they were hired.

All Middle School Graduates are initially trained in three basic functions upon entering IHI - welding, gas cutting and crane signaling. This training is accomplished within the first two to three weeks after hire. A thorough indoctrination in safety is also given all new employees.

Subsequent to the training in welding, burning and crane signaling the employee is assigned to a work group where "on-the-job" training begins. Because of the work group organization and the fact that work groups are relatively permanent and have a fixed location and routine, the integration of new employees is extremely smooth and does not adversely affect the productivity of any single group.

Additional training is provided on a formal basis for new employees depending on job skill requirements. The formal training program for these personnel is divided into either a two- or a four-year course.

As with the Middle School Graduates, High School Graduates are given two or three weeks of basic training in welding, burning and crane signaling. However, this training is a part of a four-month training course that.is not nearly as extensive as that given Middle School Graduates.

All University Graduates are hired by the Head Office in Tokyo where they spend the initial two weeks of their employment. Upon assignment to a shipyard these employees spend two weeks in the yard training school followed by two months in one of the yard's production departments. Subsequent to this training the employee is assigned to the shipyard section mutually agreed upon by the employee and the company.

Personnel who do not fit the above categories are given a one-month course in the shipyard training school after which they are assigned to a yard section requiring unskilled or semi-skilled workers.

IHI considers that the entire workforce is constantly engaged in a program of continuing education and training which provides increasing opportunity for learning and promotion within the company. The majority of training occurs "on-the-job" through the gradual improvement in knowledge and skills provided by the interaction with one's work group and with the older and more experienced employees. The requirement for training subordinates exists at every level of the organization and this training is carried out assiduously by supervision and management personnel.

## APPLICATION TO U.S. YARDS

The Japanese personnel-oriented system is one method for serving the best interests of both workers and management. Japanese concepts of private enterprise differ significantly from those of most U.S. firms in other respects also. In order to apply the "personnel-oriented" system of the Japanese, an American firm would have to re-align not only its way of doing.business but also its philosophy with regard to the objectives of the enterprise. Profit would have to be relegated to a position subordinate to the welfare of the people of the firm and to the quality of the product. This basic change in philosophy may preclude the successful adoption of the Japanese approach in the minds of many American businessmen. It should be realized, however, that Japanese corporations are nonetheless profitable and that their management practices, while radically different from those of U.S. corporations, may in fact be conductive to increased rather than reduced profits.

Aside from this basic philosophical difference, the principal obstacles to the application of the Japanese personnel system to U.S. shipyards are the attitudes extant between management and labor (unions), and the employee attitudes prevalent in U.S. industry, both of managers and workers. These attitudes can be vastly ameliorated by the introduction of many of the elements characteristic of the Japanese personnel system: full implementation of the Japanese system is however, impossible under the prevailing labor movement precepts in the U.S. In this regard, an attitude of mutual objectives and co-operation, similar to that of the Japanese, would have to develop between American labor and management both of individual firms and eventually of the whole industry.

Irrespective of labor/management attitudes, several aspects of the Japanese personnel system can be instituted in U.S. yards. For example: the IHI production organization or pieces of that organization is amenable to adaptation to a U.S. yard. Those organizational elements having to do with the production workshops, especially the use of "Staff" groups and the organization into production stages of fabrication, sub-assembly, assembly and erection, are readily adaptable to any shipyard. This would, of course, require a reorganization and reorientation of the traditional U.S. concepts of Production Planning and Control activities and, if not carefully controlled, could cause some disruption of work in process. If this reorganization was attempted, the Japanese system of planning, scheduling and production control would necessarily have to be at least partially instituted.

In the area of Benefits, U.S. firms can initiate some activity aimed at increasing the concern of the company for the employees and, hopefully, improving the image of the company in the eyes of its employees. The reciprocality of this activity would be improved labor/management relations, more identity with and allegiance to the company, and possibly a more stable workforce because of this allegiance. Improved productivity would be a natural and a necessary by-product of these positive attitudes.

Some of the benefits most amenable to adaptation are:. Bonus Programs (i.e. congratulatory/condolatory/retirement or possibly incentive-type); longevity pay scales; improved eating facilities; and provision of work clothing.

Extending these benefits into the area identified by the Japanese as Personnel Welfare Programs, U.S. yards can adopt some of the more intensive safety and sanitation methods; an extensive environment program to improve -general yard working conditions; provision of employee recreational facilities; improved in-yard medical and dental care; housing programs; and other similar programs obviously oriented toward the welfare of the employees.

Finally, the institution of a system whereby workers can be allocated to a fixed work station and work group is an important and achievable aspect of the Japanese personnel system that can be adapted to U.S. yards. This is a difficult and far-reaching undertaking for a yard not already organized by work station (for performance of certain types of work, albeit by different personnel). The many benefits deriving from the assignment of permanent work groups to a single location concern employee identity, skills improvement, use of routine or "mass production" techniques, accurate individual and group performance measurement, and the eventual development of firm estimating, cost control, and scheduling parameters. The institution of this "work group" system would require considerable change to the traditional centralized planning and control system, to the production/facility utilization system, and to the manpower allocation system utilized by most yards.

Overall, the adaptation of any of the above personnel-oriented systems or practices should enhance U.S. shipyard performance The institution of any single aspect of the Japanese personnel system should yield positive results in terms of personnel satisfaction with the company and identity with the company, and should therefore enhance the productivity of the workforce as a whole.

Every feature of the Japanese shipbuilding industry's approach to industrial relations has its return in improved productivity. Many of these features have.direct applicability in U.S. shipyards. Given a positive and cooperative attitude on the part of both shipyard

**managements and shipbuilding unions, there is every reason why many of these features should be adopted in U.S. shipyards, to the mutual benefit of stockholders and employees.**